Tangram Race Mathematical Game: Combining Wearable Technology and Traditional Games for Enhancing Mathematics Learning

By

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Abstract

The public in general and educational communities are aware of the importance of elementary math education for students’ lives and for the economy. The thesis investigates a method to enhance students’ mathematics learning and learning interest, by combining traditional outdoor games and wearable technology together.

The main teaching topic in this research is elementary school geometry, which will play a considerable role in children’s future life. Elementary math is important because students take the foundation of what they learn and apply it once they reach higher grade levels. *Tangram Race*, an outdoor physical game designed for elementary school students, is examined and tested in two studies to show that the game-based learning environment can enhance learning gains to a certain extent.
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Chapter 1: Introduction

STEM is an acronym referring to science, technology, engineering and mathematics in academia. It is also a process that integrates these four fields to solve real world problems and promote problem-based learning and teamwork. STEM is affecting every aspect of people’s lives. Science explores our natural world — the sun, rivers, trees, continents, oceans and animals… Nowadays, people cannot live without technologies such as computers and smartphones; we are all enjoying the convenience provided by all kinds of applications on our smartphones. Bridges we use, buildings we live in, air planes we ride… they are all related to engineering. We use mathematics at shopping centers, banks and restaurants when dealing with currency or investments.

STEM not only exists in everybody’s life, but also potentially affects the education of the next generation that lives in the technological age.

The U.S. Department of Commerce’s Economics and Statistics Administration (ESA) released a report that shows that over the past 10 years, growth in STEM jobs was three times greater than that of non-STEM jobs, and STEM jobs are expected to continue to grow at a faster rate than other jobs in the coming decade. Meanwhile, STEM workers are also less likely to be unemployed [1]. In 2014, technological jobs occupied the NO.1 positon for first time in the survey’s history done by the U.S. Department of Labor. The rating criteria shares one thing: STEM jobs will grow exponentially and faster than the average rate from 2012 to 2022 [2].
Figure 1 Growth in employment in STEM occupations

Figure 1: nearly all the major STEM groups have about the same rate of growth. The exception is computer specialist occupations, which are expected to grow much faster than the average. All in all STEM occupations are increasing in the speed of 22% [3].

The prospect of jobs in the STEM field seems to be optimistic. However, a new report from The Brookings Institution shows employers face difficulty finding STEM workers despite offering top wages in those fields. The study finds it takes twice as long to fill job openings for science, technology, engineering and math related jobs compared to a job outside of STEM industries. Jonathan Rothwell, Brookings senior research associate and associate fellow who authored the report, said there has been a national discussion about the importance of STEM skills and education [4].
Figure 2 shows several countries’ STEM degree cover percentage in 2011. We can clearly see United States covers only 13% STEM degrees overall. As several countries in Africa and Asia are providing quality conditions to attract foreign-educated graduates to return home. So it is essential and urgent for United States takes some actions for enhancing the STEM based education.

The global race for STEM skills might become even more competitive in the near future. An analysis of the recent National Assessment for Education Progress (NAEP) results show that over the past half-decade, nearly half of American fourth and eighth grade students fail to perform at a basic level in math and reading [5]. Poor learning result is also a signal it is necessary to lay a solid foundation in elementary STEM education.

In this thesis, I try to find a new way as a potential solution to lay a solid foundation of elementary math learning. The new method is about creating a game-based learning environment which combines traditional playground games with wearable technology.

According to Dr. Vince Bertram (President and CEO of Project Lead The Way, Inc.): It is important to offer STEM curriculum to students in elementary schools to foster their life-
long interest in learning and convince students that they can be good at math and science [6]. Compared with traditional STEM teaching methods, game-based learning can influence motivation and engagement of the learners in a positive way.

In order to present the research regarding the enhancement of math learning and the interests of students in STEM subjects, the thesis has the following structure: (2) Literature Review (3) The Game Design (4) Research Questions and Hypotheses (5) Design of First Study and Second Study (6) Results of First Study and Second Study (7) Conclusion and Future Work.
Chapter 2: Literature Review

In order to design games for closing STEM fields’ achievement gaps between America and other nations, it is essential to know the problems that exist in the US STEM education system and why games and wearable technology can provide potential solutions to these problems. In this section, I analyzed past research on the mathematical anxiety, games on education, as well as innovations brought by applying wearable technology on education. This section also serves as an initial work for the game design, densely influencing the design process in order to create a game that enhances the math learning and motivates students’ interests on mathematics.

Mathematical Anxiety

Approximately 93 percent of Americans indicate that they experience some level of math anxiety [7]. What is math anxiety? According to Mark H. Ashcraft’s definition, “Math anxiety is a feeling of tension, apprehension, or fear that interferes with math performance [8]”. Math anxiety can develop at any age. Many children may develop their negative attitude towards math at an early age. Many college students also suffer with math anxiety [9]. Math anxiety can cause many symptoms of general anxiety, including trouble sleeping and frustration. Students who suffer from math anxiety often avoid math as much as possible. Ashcraft explains that ‘math avoidance results in less competency, exposure and math practice, leaving students more anxious and mathematically unprepared to achieve’ [8]. Research also suggests that math anxiety may affect math achievement. Ma found that the relationship between mathematics anxiety and mathematics achievement is significant. Low achievement students usually have high math anxiety [10].
Then what is the cause of math anxiety? Jackson and Leffingwell’s research finds that the teachers’ attitude towards math affects students a lot. If the teacher had a negative attitude towards math, students may feel it is not important to learn math well and frequently suffer from math anxiety in future math learning [11]. And some researches show that math anxiety is related to teaching style. Generally, math teaching in most schools is delivered in traditional methods. Teachers stand on the front podium and use directed instruction with the power of authority. Students learn passively and do not question the teacher’s authority. Also teachers teach in the reference of the fixed curriculum and textbooks which may not be suitable to each student. Math teaching in traditional methods usually assumes each student has same ability, preferred learning style and pace of working. It is hardly concerned with individual difference in learning. Also, research shows that a time limit will increase students’ math anxiety. Researchers find participants had worse math performance during timed versus untimed testing. Students cannot develop their problem-solving skills and understand math concepts under time pressure. Instead of active learning students will rely on rote memorization and increase their math anxiety [12].

**Usage of Educational Games in Mathematics Education**

People have made many studies on finding solutions to relieve math anxiety. One of those methods includes educational games. A group of researchers in NYU-Poly studied the effect of a movement-based math game on reducing math anxiety in 2012. They found different power poses may have different effects on people’s emotion. Then they designed a game called ‘Scoop!’ which takes advantage of the high-power poses and find a way to shift math anxiety [13]. Games are thought to be a useful way to assist in math education. Games provide opportunities for building self-concept and developing positive attitudes towards mathematics, through reducing the fear of failure and error. Games also increase the
interaction between students; provide more opportunities to test intuitive ideas and problem solving strategies compared to traditional methods. Games can allow children to operate at different levels of thinking and to learn from each other. More importantly, games can give students timely one-on-one tutoring when they struggle on a question, which is relatively limited in traditional teaching method [14]. Papastergiou researched digital game-based learning and whether it has an impact on education effectiveness and student motivation in 2008. The sample was 88 students, who were randomly sent into two groups, one of which used the gaming application and the other used the non-gaming one. The two groups used the same pretest and posttest. Data analysis showed that the gaming approach was both more effective in promoting students’ knowledge of computer memory concepts and more motivational than the non-gaming approach [15]. However, some researches reflect teachers may have different perspectives on using computer games in class. In Demirbilek’s study, math teachers express their concern about the classroom management during the play and the lack of hardware infrastructure in the classroom [16]. Also, studies found long-term playing of computer games can result in neck aches, eyestrain and fatigue. Furthermore, overplaying video games can cause low self-esteem or aggressive behavior. Overplay can cause social isolation and poor social skill when students get addicted to playing video games [17].

Since games have so many benefits on relieving math anxiety and enhancing math learning, is there any way to create a game learning environment without exposing students to stagnant computer games? Active physical games can be a good answer to this question.

**Outdoor Physical Game**

According to research reported by Centers for Disease Control and Prevention, the percentage of obesity for children (ages 6–11 in the United States) increased from 7% in
1980 to nearly 18% in 2012. Another study shows that more than one third of children and adolescents were overweight or obese in 2012 [22]. Due to a lack of physical activity, the percentage of obese children is increasing. The Harvard School of Public Health also mentioned it is important and necessary to provide physical activity environments for children.

In the video game industry, there is a new trend of mixing more physical activity with video games. In the 1990s, the most successful one is Dance Dance Revolution which incorporated physical fitness into a game. The latest one is the Nintendo Wii, the combination of the Wiimote and the sensor bar allow games to be much more interactive, and add more physical elements to the video game experience [23]. It seems we have found a way to push people to exercise simultaneously while playing video games. However, some researches show most American children spend about 3 hours a day watching TV. Added together, all types of screen time can total 5 to 7 hours a day. Public Health England announced that too much time in front of TV and computer screens is causing increasing psychological problems, such as depression and anxiety, in children [24]. Is there any way promote children to do more physical activities without longtime exposing to screens? Playing outdoors is a form of exercise that promotes well-being and wholesome physical development. Children are naturally drawn to active play outdoors: it allows them to explore their environment, develop muscle strength and coordination, and gain self-confidence. Playing actively outdoors also increases flexibility, fine and gross motor skills and is related to the development of a wide variety of physical skills, including those involved in sports. Children have a great need for physical exercise and activity to be out in the fresh air and sunshine. They like to use their whole body when they play outdoors, and find such physical activities interesting and challenging. Outdoor playing game also offers more opportunities for creativity and free play and a chance for more social interaction with peers.
Innovations of Wearable Technology

With the passage of time, technological devices are becoming more portable and less cumbersome. *Apple* revealed its new product called the iWatch on September 9th this year, and with google glass’s earlier release, wearable technology is becoming a hot topic in technology. Wearable technology is defined as a category of technological devices that can be worn by a person and are often used for tracking information related to health or fitness [18]. Wearable technology ultimately saves time and effort by allowing consumers to move through daily tasks more quickly. Some wearable devices are equipped with sensors which will allow them to work as activity trackers and personalized digital assistants. Those uses bring out the outstanding benefits of wearable technology: light, easy to wear and capability to track physical activity information. Additionally, there has been some further research conducted to study the potential uses of wearable technology.

Chiu and Liu conducted a study on utilization of smartwatches for older adults. A RFID smart watch was designed for adults with fall detection, medical emergency alarming, vital sign recording, and medication reminder applications. But the prevalence of utilization is rather low. Then the research group created an innovative teaching model on the utilization of smart watches. The experiment was designed with two groups. Each group consists of 15 dyads of a student and an older adult. An experimental group of 15 students were enrolled in the Smart Living curriculum and a control group of 15 students were enrolled without receiving the service-learning teaching method. Results showed that students in the experimental group performed better and obtained better self-assessments for learning outcomes, older adults’ utilization of smart watches was four times longer in duration for the experimental group, and feedback from older adults in the experimental group are useful and specific, especially regarding falling detection and monitoring [19].
Similarly, Wu, Dameff and Tully did a research about using Google Glass in simulation-based training. Participants mainly used Google Glass to record things they have done and later analyzed and utilized those videos Google Glass recorded during debriefing sessions. The experiment proved researchers can successfully integrate Google Glass into simulation-based training and debriefing. The record data was used to provide instructional feed to participants for self-reflection and appraisal. By analyzing the post-exercise surveys, researchers found that Google Glass did not interfere with participants’ simulation experience [20].

In the paper by Woolf, Arroyo and Zualkernan, they mentioned that students can socially interact with each other and remotely access the information through mobile and wireless devices. Such technologies can support discussions, exploration and investigations, and recording and sharing of data. Mobile tools can make learning easier and more effective [21].

**Costello Pleasure Framework**

Brigid Costello and Ernest Edmonds addressed a pleasure framework in a paper published in 2007 - A Study in Play, Pleasure and Interaction Design. This paper describes the development of a framework of thirteen pleasures of play. By applying the framework on the design process of three interactive artworks, they found the pleasure framework is a useful tool to aid in the playful interfaces design which can motivate audiences to interact and engage with the artwork [25]. Imran A. Zualkernan developed a pleasure-based design evaluation framework based on Costello pleasure framework. The framework identifies sixteen different dimensions of pleasure. The framework is applied to three educational games to show its effectiveness in critiquing and enhancing such games [26]. *Tangram Race* utilized several points of this framework in the game design. Table 1 (Adapted from [25]) shows the definition of each point of the framework.
Table 1 Definition of each component of the framework

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creation</td>
<td>The pleasure participants get from having the power to create something while interacting with a work.</td>
</tr>
<tr>
<td>Exploration</td>
<td>The pleasure participants get from exploring a situation.</td>
</tr>
<tr>
<td>Discovery</td>
<td>The pleasure participants get from making a discovery or working something out.</td>
</tr>
<tr>
<td>Difficulty</td>
<td>The pleasure participants get from having to develop a skill or to exercise skill in order to do something.</td>
</tr>
<tr>
<td>Competition</td>
<td>The pleasure participants get from trying to achieve a defined goal.</td>
</tr>
<tr>
<td>Danger</td>
<td>The pleasure of participants feeling scared, in danger, or as if they are taking a risk.</td>
</tr>
<tr>
<td>Captivation</td>
<td>The pleasure of participants feeling mesmerized or spellbound by something or of feeling like another entity has control over them.</td>
</tr>
<tr>
<td>Sensation</td>
<td>The pleasure participants get from the feeling of any physical action the work evokes.</td>
</tr>
<tr>
<td>Sympathy</td>
<td>The pleasure of sharing emotional or physical feelings with something.</td>
</tr>
<tr>
<td>Simulation</td>
<td>The pleasure of perceiving a copy or representation of something from real life.</td>
</tr>
<tr>
<td>Fantasy</td>
<td>The pleasure of perceiving a fantastical creation of the imagination.</td>
</tr>
<tr>
<td>Camaraderie</td>
<td>The pleasure of developing a sense of friendship, fellowship or intimacy with someone.</td>
</tr>
<tr>
<td>Subversion</td>
<td>The pleasure of breaking rules or of seeing others breaks them.</td>
</tr>
</tbody>
</table>

This thesis tries to create a new game learning environment that combines both wearable technology and traditional games to enhance students’ elementary math geometry learning and motivation to learn.
Chapter 3: The Game Design

Overview
The public in general and educational communities are aware of the importance of elementary math education. Sometimes learning experience is limited when traditional teaching methods are used. This thesis talks about a game design that combines traditional outdoor games and wearable technology to enhance math learning and motivate learning interest.

Platform

Outdoor space
This game can be played at any outdoor space which allow students run freely and no potential danger.
Wearable technology (Cyber Watch)
The Figure 4 is a rendering picture of the Cyber Watch. The Cyber Watch uses the Arduino Uno, connected to a WiFly wireless module and powered by 1-2 1000 mAh Lithium batteries. Cyber Watch integrates all pieces within a casing on the forearm, via a PCB board (Figure 6). And the PCB board is specially designed by ECE students houses connections for Arduino Uno, WiFly, buttons, display.

Figure 4 Renderings of the Cyber Watch

Figure 5 Rendering of the Cyber Watch (sideview)
Gameplay Description
The game design is made up from a combination of two traditional outdoor games. One is called ‘One, two, three, Freeze’, which is a classic street game in China and is similar to the ‘Red-light-Green-light’ game played in the US. This game requires players to run and stop when they hear different signals, usually spoken by the host standing at the finish line facing the wall. The second game is called ‘Tangrams’ (Figure 8), a puzzle game invented in ancient China. It consists of seven flat shapes, which are put together to form hundreds of new combined figures.

Four teams of three players each stand behind the starting line and the host stands at the finish line facing a wall. First part of the game is collecting all the tangram pieces the players will need for later use. One at a time, each play runs to the finish line to find a potential piece that could fit the tangram. The host may turn around and shout ‘freeze’, which requires the players to stop running and stay still. If a player does not stop, the host sends him back to the starting line. At the finish line, there are four baskets containing a variety of puzzle pieces that may include triangles, parallelograms, and squares. To determine which component shapes students need to take, they are given clues on a display screen that may be worn on the wrist. The screen displays hints in the form of different mathematical problems (See Appendix A), which helps the players to pick the right pieces.
for the puzzle. One player from each team races to the finish line, takes two tangram puzzle pieces and runs back to the starting line. Only one player from a team may be allowed to run at a time. Once all three players have returned to the starting line with the right tangram puzzle pieces, only then can they proceed to the final task of the game. A game scene below (Figure 7) gives you a better idea of the gameplay.

![Game Scene](image)

**Figure 7 Game Scene**

Each team collects twelve puzzle pieces and puts them together in minimal time at the starting line table. Next, players work together and choose seven pieces of the tangram to finish. Players accept pieces based on a reference figure. The reference figure shows the final puzzle structure (bottom line on Figure 8). According to different reference figures, various levels were designed. In Easy Level, the outside edges and each sub-components of the final figure are provided. In Difficult Level, only the outside edges of the final figure are provided, students have to figure this out by themselves (See Appendix K).
Key Features

Wearable technology
By wearing the Cyber Watch, players can run, pick up tangram pieces and play without hindrance. Also, it’s much easier to give new clues and timely help to players with Cyber Watch. After studies, we will develop more features of the technology to implement the game.

Game Mechanics

Core Game Play
All the players are divided into several groups and each of them has three players. In the first part of the game, players run fast to pick up right tangram puzzle pieces in the finish line baskets according to the clues on their armband display. While running, they also need to pay attention to the host’s command which instructs them to stop and stay still. Otherwise, anyone who moves will be sent to the starting line. After all the players in a team finish collecting tangram puzzle pieces, they will jump to the second part of the game. A reference figure will be put on each table at the starting line. Players need to choose the right pieces and put them together to form a figure like the reference figure on the table. During this gameplay, players can partake in team competition, learn how to behave in a team, and gain
math knowledge at the same time. By playing ‘Tangrams’, geometry knowledge can be reinforced through problem-solving activities.

**Gameflow**
The figure 9 shows the gameflow. And the dashed box is the gameflow of the first part of the game and Tangram is the second part.

**Level Design**
This game is designed into two levels. Different levels of two game parts can be combined freely according to players learning ability.

* First level
  In the first part, players will be given more detailed and easier hints. They may be provided with the color and the name of the shape, for example: “Red Triangle” or “Yellow Square”.
  In the second part, reference figure will be drawn with the whole outline and more inner lines (See Appendix K).

* Second Level
  In the first part, players will be given only the attributes of the puzzle pieces, for example: “I have three angles and three sides”. Name and color information will not be provided.
  In the second part, reference figure will be drawn only with the outlines (See Appendix K).

**Victory Conditions**
The team with the shortest time to finish the game will win. In the first part, each team member runs as fast as they can and picks up puzzle pieces based on the clues. The team that completes the first part in the shortest time proceeds first to the second part. In the second part, each team member contributes to finish the puzzle in the shortest time.

**Number of Players**
This game is played with at least two teams of 3 players each. The number of players may be increased by multiples of three.
Figure 9 Gameflow
**Game Play Elements**

* Display Screen

Display screen is located on the center of the armband and it is used to help the players in the game. Additionally, there are four buttons around the display. The buttons are: question, hint, back and next. The question button offers clues about the puzzle pieces that the players need to obtain, and the hint button gives more details about the puzzle pieces that is an important feature to help students to learn. Players can hit back or next button to move on.

* Host

Host usually stands near the finish line facing the wall. He or she interacts with players by turning around and shouting out commands at random times: ‘one, two, three, freeze!’ As soon as players hear this command while running, they must stop and stay still. If any of them moves or does not stop immediately, they have to start again from the starting line.

* Tangram puzzle pieces

The puzzle pieces include various kinds of shapes which are our potential teaching points. It is hard and important for players to collect puzzle pieces according to clues on displays. Because there are more puzzle pieces in the basket than they need. Then they need to choose seven pieces out of fourteen and put them together to finish the puzzle. Players can potentially get a better understanding of the attributes of shapes in the gameplay.

**Game Goal**

The game goal is to collect and finish putting up puzzle pieces in a short time. The game goal is not only to have fun, but players can learn the knowledge of shapes and enhance learning interests by playing this game.
**Game Analysis According to Costello Pleasure Framework**

This game covers eleven points of Costello pleasure framework [25]. Table 2 shows the details of the game analysis.

<table>
<thead>
<tr>
<th>Creation</th>
<th>Players use tangram pieces they collected in the first part of the game to build up different figures. When they finish the figure, they will get a feeling of accomplishment and the pleasure of creation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>When players arrive to the finish line, they need to find the right pieces in the baskets according to the clues on the display screen. During the build-up tangram process, players try different possibilities to make a concrete figure.</td>
</tr>
<tr>
<td>Discovery</td>
<td>According to the clues on display screen, players need to find right pieces. In the build-up tangram process, players in a team work together and find a solution to the tangram puzzle.</td>
</tr>
<tr>
<td>Difficulty</td>
<td>Since players haven’t gained related knowledge of the clues, they may have some difficulties to find right pieces in the basket. During the running, if the host turn around and shout “freeze”, everyone should stop and stay still, if any player continues to move, he is sent to the starting line. The game design adds some difficulties in the build-up tangram process. In Easy Level, the outside edges and each sub-components of the final figure are provided. In Difficult Level, only the outside edges of the final figure are provided, students have to figure this out by themselves.</td>
</tr>
<tr>
<td>Competition</td>
<td>The game usually has 2-4 teams and each team has three players. The game goal is use minimal time to finish the final figure. Each team is competing with each other under time pressure, and they need to run fast, “freeze” timely and build up the tangram quickly.</td>
</tr>
<tr>
<td>Captivation</td>
<td>There are many irrelevant pieces which interfere with the players when they are looking for the right pieces.</td>
</tr>
<tr>
<td>Sensation</td>
<td>The racing and time pressure makes players feel nervous, excited and highly immersed in the game.</td>
</tr>
<tr>
<td>Sympathy</td>
<td>While one of the players running to get tangram pieces, other two players in a team standing in the starting line may also feel nervous, excited and worried. They share the same emotional feelings with their team members.</td>
</tr>
<tr>
<td>Fantasy</td>
<td>When players finish building up the tangram, they can identify what figure it is and get a pleasure of fantasy.</td>
</tr>
<tr>
<td>Camaraderie</td>
<td>Friendship can be easily built in teams since people share common goals. In this game, players in the same team must work hard together to get all the pieces they need and build up the figure as soon as possible. Players in the same team help each other to win the game.</td>
</tr>
<tr>
<td>Subversion</td>
<td>The biggest subversion is the game itself. To players, playing this game is not only having fun, it also a learning process. They can</td>
</tr>
</tbody>
</table>
gain mathematical knowledge while playing games in the playground instead of learning math while sitting in the classroom.
Chapter 4: Research Questions and Hypotheses

Research Questions
This thesis investigates some learning issues exist in STEM courses. Some researches indicate that students can relief their math anxiety through playing educational games. But we still don’t know if educational games can also enhance the math learning compared with a stagnant classroom teaching. Besides, there are so many benefits of outdoor physical game and innovations of wearable technology. We want to combine these two factors together and to see the results. Given to previous studies on the topic of whether a combination of outdoor physical games and wearable technology can enhance math learning are not clear, so our first research question is: can a combination of outdoor physical games and wearable technology enhance elementary math learning?

Meanwhile, learning interest is the motivation of learning. Some researcher pointed out that problem-based learning may attract students’ attention and potentially improve students’ learning interests. In a game content, there are many chances that problem-based learning can happen. Given to there is no clear answer of whether students can improve their learning interests after playing educational game, so our second question is: can players improve their learning interest thanks to the game learning environment?

Those questions will be addressed in two studies. The first study will use the mock technology and the second study will use the wearable technology - Cyber Watch.
Chapter 5: Design of First Study and Second Study

**Introduction**
The first study was a usability study where students played the game with mock technology. And analyzed the hypotheses even with the mock technology. The first study served to improve the game design and got more inspiration for the design of the wearable technology through the feedback and data analysis. Second study tries to test the usability of the wearable technology – Cyber Watch. We expected to see some advantages brought by the smart watch to the gameplay and if the smart watch can bring more learning excitement to students.

**First Study Methodology**

**Participants**
Our participants were nighty-six (96) first grade students from a local elementary school in Bengbu City, Anhui province, China. They were between seven to eight years old.

**Experiment Description**
Forty-eight (48) students were sent to the control group and forty-eight (48) students were sent to the experimental group. Both groups did the same pretest and pre-survey before the experiment.

Forty-eight (48) students in the control group were taught elementary geometry through a traditional method – sitting in the classroom taught by teachers standing in front of a podium. The learning goal was to have students identify attributes of four shapes (Triangle, Square, Rectangle and Circle). The teacher drew four shapes on the blackboard, asked questions about the names of the shapes, and taught the students the attributes of each shape. Figure 10 shows the scenario. This process lasted about 20 minutes. Later, students did the posttest and post-survey.
There were forty-eight (48) students in the experimental group played the game on the playground. The first study applied a mock technology shown in Figure 11. Removable paper was attached on the players’ sleeves which gave questions of the puzzle pieces.
Students were divided into four equal groups. The experiment ran four times with four groups and each group had twelve students. Before playing, the teacher took out four plastic shapes and quizzed the students about the names and attributes of those shapes. This informal teaching process lasted about five minutes. Since it’s a team based game, twelve players were divided into four teams. Three players of each team stood in a row at the starting line. Only one player from a team was allowed to run at a time. While the students were running, the host stood at the finish line facing the wall and then turned around to shout commands at a random time: ‘One, two, three, freeze!’ All the running players stopped and stayed still while listening for commands. Any player that moved had to start again from the starting line. Once all three players had returned to the starting line with the right tangram puzzle pieces, the players can proceed to the final task. In the second part, each team was given a reference figure of a tangram; team members worked together and put tangram pieces together to form the figure. Figure 12 shows the gameplay scenario. This game lasted about 15 minutes. After the game, each students did the posttest and post-survey.

Figure 12 Gameplay Scenario
Data Collection Instruments
In developing the data collection instrument, we considered the test and survey’s three main purposes:

* Evaluating students’ math performance between two groups (control group and experimental group). We can analyze math performance variation based on the pretest and posttest math score to see whether the game learning environment is effective.

* Tracking students’ attitude towards math. Through analyzing the pre-survey and post-survey results, we can consider whether there is a change in the students’ attitudes (confidence or interest) towards math after the experiment.

* Improving the game design. By observing the experiment and analyzing feedback, we may find some better ideas to improve the game design.

The pretest and posttest were designed based on math common core standards. The pretest aims to see whether two groups of students are basically in the same level. The pretest (See Appendix B) content assessed the students’ ability to write down the shape’s name according to a given pattern and to see if the students recognize specific shapes. The posttest (See Appendix C) aimed to quantify how much the students learned from each teaching method. The content of the posttest included the four shapes’ attributes and the concepts of sides and angles.

The pre-survey (See Appendix D) and post-survey (See Appendix E) have five questions each and each question has a scale of 1 to 5. The same pre-survey was taken by both groups before the experiment; the survey aimed to know the students’ attitude towards math. The groups took different post-surveys after the experiment. The post-survey taken by the experimental group aimed to know how much students like playing the game, whether they learnt any math while playing and what was
their attitude towards learning math in the future. The post-survey taken by the control group aimed to know whether students wanted to learn math by playing games and what was their attitude towards math in the future.

**Data Collection Procedures**

Paper copies of tests and surveys were given to each group. These tests and surveys were collected by researchers at the end of each time period. Later, all the data were digitalized and then analyzed. The data was also tabularized in order to get a better understanding of the results.

**Second Study Methodology**

**Participants**

Our participants were fifteen third-grade students from an after-school program in Shrewsbury, Massachusetts. Most of them are minorities.

**Experiment Description**

We introduced the purpose of this study and gave a brief introduction of the game. We gave students a 5-minute informal lesson: we asked questions about the attributes of several basic shapes and provided conclusions about those basic shapes. Then all the students took a pretest and survey with no time limit. Most of students finished the test and survey in 15 minutes. Afterwards we explained the game rules in detail and modeled the gameplay to the students (See Figure 13 and 14).
We showed how to use the watch. The Cyber Watch has an OLED display on the top and four buttons in the corners surrounding it. The four buttons are: Question, Hint, Back and Next. Players hit the “Question” to get the puzzle clue. If they cannot figure out what the puzzle piece is, they can hit the “Hint” to get more information. When the players have accomplished the first task and have retrieved the second puzzle piece, then the players can...
hit the “Next” button to check the second clue. They can additionally hit the “Back” button to review the last question and hint.

Due to the limited amount of Cyber Watch, we divided all the students into two groups. The first group consisted of nine students and the second group consisted of six students. We let students in the second group played after the first group. The first group of students was divided into three teams and each team contained three players. After all the players set up the Cyber Watches, the game started. The first player ran to the finish line and picked up a singular potential puzzle piece from the baskets then ran back. And the second player was readied to run. This relay continued until they had collected all the fourteen potential puzzle pieces. During the relay, to add entertainment value and difficulty, a host stood at the finish line facing the wall. She would randomly turn around and say: freeze or unfreeze. When she said ‘freeze’, all the running players stopped and stayed still, and anyone who moved was sent back to start again. When she said ‘unfreeze’, they continued running. After collecting all fourteen pieces, each team began playing the Tangram puzzle. Each team was given a reference figure for their puzzle. The size of the reference figure was much smaller than the actual puzzle, which prevented players from putting pieces directly on the reference figure.
to finish the puzzle. The second group students played exactly the same game as the first group. Below are pictures of the gameplay.

![Gameplay Scenario - Racing](image)

**Figure 16 Gameplay Scenario - Racing**

![Gameplay Scenario – Tangram](image)

**Figure 17 Gameplay Scenario – Tangram**

After the game, all the players did a posttest and a survey with no time limit. Most of the students finished in 15 minutes. In the end, everybody was given a prize. The winning team gained an extra ‘WPI badge’.
Data Collection Instruments
In developing the data collection instrument, we considered the test and survey’s three main purposes:

* Evaluating students’ math performance before and after the experiment.
* Tracking students’ attitude towards math and collecting feedback of the game.
* Improving the design of the wearable technology. By observing the gameplay, we tried to detect the usability of the Cyber Watch and may find some new ideas for polishing the watch.

The test1 and test2 were consisted of 4 questions and two of them appeared on the previous MCAS mathematics tests (See Appendix G and H). Questions in the two tests were quite similar. Although questions were different, but they all tested the same mathematical principle and covered topics included in the game. Based on third grade math common core standards, the two tests mainly covered the knowledge of shapes in different categories, parallel lines and a review of angles and sides.

The pre-survey (See Appendix I) and post-survey (See Appendix J) were based on a five-point Likert Scale. For students got a better understanding of the survey, there was a corresponding pain-scale face above each scale. The pre-survey consisted of 5 questions which aimed to know students’ attitude towards math before the game. The post-survey consisted of 8 questions which aimed to know students’ feeling towards the game and their attitude towards math after the game.

Data Collection Procedures
In order to avoid test data inaccuracy, we handed out test1 to half of the students and test2 to the other half in the pretest time. Then reverse them in the posttest time. Survey was distributed once students finished the test. Later all the data were digitalized.
Chapter 6: Results of First Study and Second Study

First Study Results

Test Results

Descriptive Statistics

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>81.04</td>
<td>13.875</td>
<td>48</td>
</tr>
<tr>
<td>Experiment</td>
<td>89.38</td>
<td>9.765</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>85.21</td>
<td>12.647</td>
<td>96</td>
</tr>
</tbody>
</table>

Tests of Between-Subjects Effects

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>12163.587^a</td>
<td>2</td>
<td>6081.793</td>
<td>186.531</td>
<td>.000</td>
<td>.800</td>
</tr>
<tr>
<td>Intercept</td>
<td>207.126</td>
<td>1</td>
<td>207.126</td>
<td>6.353</td>
<td>.013</td>
<td>.064</td>
</tr>
<tr>
<td>PreTest</td>
<td>10496.920</td>
<td>1</td>
<td>10496.920</td>
<td>312.944</td>
<td>.000</td>
<td>.776</td>
</tr>
<tr>
<td>Group</td>
<td>1027.177</td>
<td>1</td>
<td>1027.177</td>
<td>31.504</td>
<td>.000</td>
<td>.253</td>
</tr>
<tr>
<td>Error</td>
<td>3032.247</td>
<td>93</td>
<td>32.605</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>712200.000</td>
<td>96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>15195.833</td>
<td>95</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. R Squared = .800 (Adjusted R Squared = .796)

Figure 18 Test Result

The posttest result of two groups has significant difference accounting to the pretest.

Survey Results

* Experimental Group Pre-survey (In a scale 1 to 5)

<table>
<thead>
<tr>
<th>Questions</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compared to most of your other school subjects, how good are you in math?</td>
<td>3.9</td>
</tr>
<tr>
<td>In general, do you think math is interesting?</td>
<td>4.2</td>
</tr>
<tr>
<td>How good would you be good at learning something new in math?</td>
<td>3.9</td>
</tr>
<tr>
<td>In general, how confident are you when you solving math problem?</td>
<td>3.5</td>
</tr>
<tr>
<td>How much do you like math?</td>
<td>4</td>
</tr>
</tbody>
</table>
* Control Group Pre-survey (In a scale 1 to 5)

Table 4 Control Group Pre-survey

<table>
<thead>
<tr>
<th>Questions</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compared to most of your other school subjects, how good are you in math?</td>
<td>3.6</td>
</tr>
<tr>
<td>In general, do you think math is interesting?</td>
<td>3.9</td>
</tr>
<tr>
<td>How good would you be good at learning something new in math?</td>
<td>3.6</td>
</tr>
<tr>
<td>In general, how confident are you when you solving math problem?</td>
<td>3.8</td>
</tr>
<tr>
<td>How much do you like math?</td>
<td>4.3</td>
</tr>
</tbody>
</table>

* Experimental Group Post-survey(In a scale 1 to 5)

Table 5 Experimental Group Post-survey

<table>
<thead>
<tr>
<th>Questions</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>How much did you enjoy playing this game?</td>
<td>4.7</td>
</tr>
<tr>
<td>Did you learn any math by playing this game?</td>
<td>4.5</td>
</tr>
<tr>
<td>Would you play it again?</td>
<td>4.5</td>
</tr>
<tr>
<td>After playing this game, do you think math is interesting?</td>
<td>4.5</td>
</tr>
<tr>
<td>Are you confident in learning math in the future?</td>
<td>4.2</td>
</tr>
<tr>
<td>Do you prefer to learn math in the playground by playing games or sitting in the classroom taught by teachers?</td>
<td>4 (75% students choose outdoor playing)</td>
</tr>
</tbody>
</table>

* Control Group Post-survey (In a scale 1 to 5)

Table 6 Control Group Post-survey

<table>
<thead>
<tr>
<th>Questions</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you want to learn math by playing games?</td>
<td>4.2</td>
</tr>
<tr>
<td>Do you think math is an interesting major?</td>
<td>3.7</td>
</tr>
</tbody>
</table>
How much do you understand the content in today’s class? 4
If you were to list the students in your class from the worst to the best in math, where would you put yourself? 3.8
Do you think it is important to learn math well? 4.5

Figure 19 and 20 display the results of statistical data of the experimental group and their math interest before and after the game. We determined that more students found math to be very interesting after playing the game.

Figure 21 and 22 display the results of statistical data of the experimental group and their math confidence before and after the game. We determined that more students are very much confident in their math solving abilities after playing the game.
Figure 23 and 24 display the results of statistical data of both groups and how much they learned after the experiment. We determined that more students in the experimental group learned more than those students in the control group.

**Discussion**

**Test**
The result of the first study supported the hypotheses that players can enhance their math learning and motivate themselves to learn math in the game environment. From the pretest and posttest results of the two groups, the significance value of the Pre-Test and the Group is 0.000, that showed the posttest results between the two groups has significant difference from the groups’ initial, similar pretest results. Also, the posttest mean value of the experimental group is much higher than the control group, which addressed the fact that the experimental group’s achievement in math is greater than the control group (See Figure 18).

**Survey**
In the pre-survey, 50% of students from the experimental group think math is very interesting; in the post-survey, 73% of students from the experimental group think math is very interesting (See Figure 19 and 20). Many more students feel confident in solving math problems after playing the game. In the pre-survey, 25% of students from the experimental group feel very confident in solving math problems; in the post-survey, 56% of students from the experimental group feel very confident in solving math problems in the future (See
Figure 21 and 22). More students feel confident in solving math problems after playing the
game. In the post-survey of control group, 53% of students learned all the content in the
day’s class; in the post-survey of the experimental group, 63% of students learned all the
content by playing the game (See Figure 23 and 24). More experimental group students
learned all the content after playing the game.

**Issues**
In this usability study, we found some issues existed in the game design. We did not
consider the victory condition and the level design, which are crucial game elements. It may
increase the entertainment value to the gameplay if we implement victory conditions and
different levels to the game. And an observer is needed to time each team in the later study.

Also, we found the mock technology was very inconvenient in the gameplay. We had to
pause the game when we needed to change the tangram pieces’ clue, which broke the
gameplay rhythm somehow. And players could not get timely help when they did not know
the clue’s answer. Hopefully, wearable technology can solve the issue in the later study. As
for the survey, we found some students cannot understand the meaning of each numeric
scale in the survey. So we will design a new format survey which uses emotional faces to
express opinions as an answer to each question.
Second Study Results

Test Results

<table>
<thead>
<tr>
<th>Paired Samples Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Paired Test 1 Pretest</td>
</tr>
<tr>
<td>Posttest</td>
</tr>
</tbody>
</table>

Paired Samples Test

<table>
<thead>
<tr>
<th>Paired Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Paired Test 1 Pretest - Posttest</td>
</tr>
</tbody>
</table>

Figure 25 Second Study Test Result

The pretest and posttest result has significant difference.

Survey Results

* Pre-survey (In a scale 1 to 5)

Table 7 Pre-survey (Second Study)

<table>
<thead>
<tr>
<th>Questions</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you think math is an interesting subject?</td>
<td>4.2</td>
</tr>
<tr>
<td>In general, how confident are you when solving math problem?</td>
<td>4.2</td>
</tr>
<tr>
<td>How good would you be at learning something new in math?</td>
<td>4.2</td>
</tr>
<tr>
<td>How much do you like math?</td>
<td>4.5</td>
</tr>
<tr>
<td>Compared to most of your other school subjects, how good are you in math?</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Post-survey (In a scale 1 to 5)

Table 8 Post-survey (Second Study)

<table>
<thead>
<tr>
<th>Questions</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>After playing this game, do you think math is an interesting subject?</td>
<td>4.2</td>
</tr>
<tr>
<td>How confident are you when solving math problem in the future?</td>
<td>4</td>
</tr>
<tr>
<td>In the future, how good would you be at learning something new in math?</td>
<td>4.9</td>
</tr>
<tr>
<td>After playing this game, how much do you like math?</td>
<td>4.8</td>
</tr>
<tr>
<td>Do you prefer to learn math in the playground by playing games or sitting in</td>
<td>42%</td>
</tr>
<tr>
<td>the classroom taught by teachers?</td>
<td>classroom</td>
</tr>
<tr>
<td></td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>playground</td>
</tr>
<tr>
<td>How much did you enjoy playing this game?</td>
<td>4</td>
</tr>
<tr>
<td>How much you learnt by playing this game?</td>
<td>3.8</td>
</tr>
<tr>
<td>Would you play it again?</td>
<td>4</td>
</tr>
</tbody>
</table>

Discussion

Test
Due to the fact that one student left early and did not finish the posttest and survey, we collected only 14 students’ tests and survey data. The second study tests result indicated that by playing Tangram Race, students improved their math score to a certain extent. In the pretest, the mean value was 65 and the value was increased to 74 in the posttest. And the result displayed a significant difference between two tests. That showed players got some learning gains in the gameplay. However, we found the mean value is lower than the test result in the first study. We thought this issue may come from two reasons: sample population and the test. We thought a racial math achievement gap may exist in the sample population; most of the students are African-Americans which may have a lower achievement in math. Another reason may come from the tests’ questions. Although all the
participants were in third grade from an after-school program and the tests’ questions were taken from MCAS third grade mathematics tests, the participants may have different levels of math learning. Some of the questions may be too difficult for some participants and that may lead to the relatively low average score. And due to a limit amount of the sample population, we could not make a learning method comparison between the traditional learning method and the game learning method.

Survey
Considering the two surveys, we asked students their attitude towards math before and after the game and their feelings about the game. In the pre-survey, the average value to the question “how good would you be at learning something new in math?” was 4.2, but the average value was upgraded to 4.9 in the post-survey. That is a good signal for this game learning environment, which indicates students had more confidence in future math learning. Also the average value improved slightly to the question “how much do you like math?” compared with the pre-survey. That suggests the game may spark students’ learning interests. There were several questions related to the game. The average value to the question “how much did you enjoy playing this game?” was 4. Most of participants gave a high rating to the game and most of the participants wanted to play this game again. That indicates the game is appealing to players and has its entertainment value.

Impressively, we found 3 players in the same team responded “not at all” to the post-survey questions. “Not at all” was one of the rating options of the survey questions, which represented scale 1 on a five-point Likert Scale. Interestingly, that team was the last one finished the puzzle. However, these players’ performances in the tests were not bad; one of the players even improved her score from 62 to 78 in the posttest. So this makes us wonder: will a failure in the competition game cause negative attitude towards future math learning? In order to mitigate this side effect on students’ attitude towards math, we may change the
game rules in other ways. Instead of competing among teams, each team could compete with time. Each team would need to finish the puzzle in a certain amount of time, and the team that finished puzzle first could help with other teams. Ideally, everybody would win the game and get the same game prizes in the end.

**Issues**
Some other issues appeared in the experiment.

For the game:

a) We noticed some players got confused about which basket belonged to their team, so we will put a bigger sign on the basket to make it more visible.

b) Some players were not sure how many puzzle pieces they got, so they did not know when to stop running and start putting puzzles together. We assume that adding a Radio Frequency Identification (RFID) to the Cyber Watch and Tags on puzzle pieces will fix this issue. Players will swipe their Cyber Watch to mark found puzzle piece and that information will be recorded to the database. Once each of them collected four pieces, they can stop running and work on the puzzle.

c) We also think it is essential to prepare prizes for every player. In the end of the game, some players asked us for game prizes and they behaved very excited when they received the prizes. So we thought prizes were critical element to inspire students’ learning interests.

d) Moreover, the size of the reference figure is another issue. Some players put the puzzle pieces directly on the reference figure to find a solution. However, the figure size is not to scale, so a big triangle may fit in a middle triangle on the reference figure which will confused players. So we will make the reference figure’s size small enough to make it impossible to let the puzzle pieces fit on any part of the reference figure.
For the Cyber Watch:

a) Some players complained about the watch band being too tight or loose. So we will redesign the watch band to make it more secure and comfortable.

b) Interestingly, we found some players directly hit the hint button to get the puzzle piece’s answer without reading the question. This is not only unfair to other teams, but also they cannot learn as much as they read the question first and then answer the question by themselves. So we need to change the button mechanics to let the hint button to not show the hint until the question button is pressed.

c) Also we noticed different players had different reading speed, so we will add buttons to control the text scrolling rate.
Chapter 7: Conclusion and Future Work

The goal of this thesis is to create a new game learning environment and to see whether students can enhance their math learning and improve their learning interests in this game learning environment. In order to verify the hypotheses, we conducted two studies.

The first study was a usability study. Forty-eight (48) students (7-8 years old) were assigned to a control group and 48 to an experimental group. Both groups filled out the same pretest and survey before the experiment and same posttest and similar surveys afterwards. The learning goal was to identify attributes of four shapes (triangle, square, rectangle and circle). Students in the control group were taught geometry through a traditional method – sitting in the classroom taught by teachers. Meanwhile, students in the experimental group played the Tangrams Race game at the playground, using a mock technology. The analysis from pre-test to post-test comparison indicated a significant difference in math learning (p<.001) benefitting the Tangrams Race group. So the test results verified one of our hypotheses: the game learning environment which combines outdoor games and wearable technology can enhance math learning. And the analysis from pre-survey to post-survey indicated a significant difference in perception of how much they had learned (p<.001). Also, motivational/affective surveys showed a 23% increase in math interest for the experimental group, as well as a 30% increase in “confidence” in being able to solve math problems in the future. Those results indicated another hypothesis: players can improve their learning interests thanks to the game environment. We also got some new inspirations for the design of the wearable technology in this study.

In order to test the usability of the Cyber Watch, we ran a second study. This study conducted in an after-school program in Shrewsbury, MA which included fifteen third grade students. Students were given pretest and survey before the game and similar posttest and
survey afterwards. The learning goal was to identify quadrilaterals and knew the concept of parallel lines. Students played *Tangram Race* game with the Cyber Watches. The analysis from pretest to posttest showed a significant difference in math learning after playing this game. That indicated students enhanced their math learning in this game learning environment. Also, the surveys indicated a 17% increase in being good at learning something new in math in the future, as well as a 6% increase in “like learning math” in the future. The results showed students improved their learning interests thanks to the game learning environment.

The players experienced a new learning experience instead of focusing on memorization. We conclude that the learning could happen in three moments. First learning happens during the first reading at the starting line. Students read the questions and retrieve their related knowledge to answer the question. If they cannot solve the question, then the hint provides more detailed information and they could learn some new features of shapes at that time. Second learning happens during the search in the basket. Students need to use what they learnt to get the right shape. Meanwhile, they can check the clue and read the question again while choosing shape. In this moment, students review the knowledge while with actual see and touch potential shape that matches the question. This process provides a more intuitive learning experience. Third learning happens when they play with the tangram. Students choose potential shapes and try to find a solution to put them together to finish the puzzle. In this process, they play with shape pieces: rotate and reverse them in different ways, which enhances their previous learning knowledge. Students reflect what they learnt during the game and combine their experience of playing tangram in the posttest.

Meanwhile, the first version of the Cyber Watch is workable for the game. Compared with the mock technology, wearable technology brought much more convenience. We did not need to pause the game to change the questions and players could see different clues just by
hitting the back or next button. And the hint button served as a help button provided more clues for players.

However, due to time constraints, there are still some issues that have not been solved. More functions of the Cyber Watch will be developed in the future to fit the game better. We will add the RFID to the watch, which can record how many puzzle pieces each team has collected and check whether players get the right puzzle piece. Also we will create a database to record each student’s performance. And we plan to add a teacher panel. It is a front-end web-based dashboard enables teachers to start the game, verify progress, and determine who is the winner team/person, as well as to enter new questions. The teacher can project this in front of the classroom to recreate the order of events and moves that students made. This allows students to explain their thinking and reasoning and to revisit moves. Learning can happen at two moments: during the game (opportunities to experience concepts and ideas) or after the game (retrospection and analysis of errors/successes). And a WiFly will be added to support communication to the central server. In addition, the sample size of the second study was far too small to get data-based certainty results, so we will make another study with a larger amount of students with a control group in the future. Furthermore, in order to tell if the students can be motivated by playing this game, a long-term study is required.
Reference


Appendix A

First Study Game Questions:

Below is the game questions shown on the mock technology in the first study. Each player was given the same four kinds of questions which may appear in different orders.

1. I have three sides. (Triangle)
2. I have four equal sides. (Square)
3. I have two long sides, two short sides. (Parallelogram)
4. I am round, I don’t have any angle. (Circle)
Appendix B

First Study Pretest:

Below is the pretest given to all the students before the experiment. There is no time limit for completing the test. Most students finished within 8 minutes. The goal of the pretest was to see whether two groups of students were in the same learning level.

1. Draw the shape that comes next to complete the pattern. Then name the pattern using letters.

1) [Diagram of shapes]

2) [Diagram of shapes]

2. Color the triangles. Then, answer the question.

[Diagram of shapes]

How many triangles did you color? ____________
Appendix C

First Study Post-test:

Below is the posttest given to the students after the experiment. There was no time limit for completing the test. Most students finished within 10 minutes. The goal of the test was to see how much students learnt after two types of teaching methods.

<table>
<thead>
<tr>
<th>Name</th>
<th>Class</th>
<th>Sex</th>
<th>Age</th>
<th>Group</th>
</tr>
</thead>
</table>

1. Draw lines to connect both sides.

- I have 4 equal sides.

- I have 2 long sides, 2 short sides.

- I am round and no angles.

- I have 3 sides.
2. Write how many sides are in each shape.

[Diagram of shapes: square, pentagon, hexagon, triangle]

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3. Write how many angles are in each shape.

[Diagram of shapes: rhombus, triangle, rectangle, circle]

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Appendix D

First Study Pre-survey:

Below is the pre-survey given to all the students before the experiment. There is no time limit for completing the survey. The goal of the survey is to know the students’ opinion towards math.

<table>
<thead>
<tr>
<th>Name</th>
<th>Class</th>
<th>Sex</th>
<th>Age</th>
<th>Group</th>
</tr>
</thead>
</table>

1. Compared to most of your other school subjects, how good are you in math?
   - 1 □
   - 2 □
   - 3 □
   - 4 □
   - 5 □
   A lot worse in math
   - Middle
   - A lot better in math

2. In general, you think math is...
   - 1 □
   - 2 □
   - 3 □
   - 4 □
   - 5 □
   Very boring
   - Middle
   - Very interesting

3. How good would you be at learning something new in math?
   - 1 □
   - 2 □
   - 3 □
   - 4 □
   - 5 □
   Not good at all
   - Middle
   - Very good

4. In general, how confident are you when solving math problems?
   - 1 □
   - 2 □
   - 3 □
   - 4 □
   - 5 □
   Worried
   - Confident

5. How much do you like math?
   - 1 □
   - 2 □
   - 3 □
   - 4 □
   - 5 □
   Not at all
   - Sort of
   - Very much
Appendix E

First Study Post-survey:

Below is the post-survey of the first study. Two groups took different post-surveys after two learning methods. The goal of the survey is to know whether there is a change towards math after two teaching methods.

<table>
<thead>
<tr>
<th>Name:</th>
<th>Class:</th>
<th>Sex:</th>
<th>Age:</th>
<th>Group (Game):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. How much did you enjoy playing this game?
   - 1 Not at all
   - 2 Sort of
   - 3 Very much

2. Did you learn any math by playing this game?
   - 1 Not at all
   - 2 Sort of
   - 3 Very much

3. Would you play it again?
   - 1 Never again
   - 2 Maybe
   - 3 Definitely

4. After playing this game, do you think math is interesting?
   - 1 Not at all
   - 2 Sort of
   - 3 Very much

5. Are you confident in learning math in the future?
   - 1 Not at all
   - 2 Sort of
   - 3 Very much

6. Do you prefer to learn math in the playground by playing games or sitting in the classroom taught by teachers?
   - Classroom
   - Both are fine
   - Play games
<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Scores</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Do you want to learn math by playing games?</td>
<td>1, 2, 3, 4, 5</td>
<td>Not at all, Sort of, Very much</td>
</tr>
<tr>
<td>2</td>
<td>Do you think math is an interesting major?</td>
<td>1, 2, 3, 4, 5</td>
<td>Not at all, Sort of, Very much</td>
</tr>
<tr>
<td>3</td>
<td>How much do you understand the content in today's class?</td>
<td>1, 2, 3, 4, 5</td>
<td>Very little, Part of, All</td>
</tr>
<tr>
<td>4</td>
<td>If you were to list the students in your class from the worst to the best in math, where would you put yourself?</td>
<td>1, 2, 3, 4, 5</td>
<td>One of the worst, Middle, One of the best</td>
</tr>
<tr>
<td>5</td>
<td>Do you think it is important to learn math well?</td>
<td>1, 2, 3, 4, 5</td>
<td>Not at all, Sort of, Very much</td>
</tr>
</tbody>
</table>
Appendix F
Second Study Game Questions &Hints:

Below are the game questions and hints displayed on the wearable Cyber Watch in the second study. Each player was given the same four kinds of questions which may appear in different orders.

<table>
<thead>
<tr>
<th>Question</th>
<th>Hint</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have 3 angles, but only 1 of them is a right angle.</td>
<td>3 angles, 3 sides and 1 right angle make a right triangle</td>
</tr>
<tr>
<td>I am a quadrilateral. All my sides have the same length.</td>
<td>I also have 4 right angles. So: 4 equal sides, 4 right angles, make a square</td>
</tr>
<tr>
<td>I have 2 long sides and 2 short sides, and my 4 angles are right angles.</td>
<td>Rectangles have 2 long sides, 2 short sides and 4 right angles</td>
</tr>
<tr>
<td>I have 2 long sides and 2 short sides, but I don't have ANY right angles at all.</td>
<td>I am called a &quot;parallelogram&quot;, because I have 2 sets of parallel sides.</td>
</tr>
</tbody>
</table>
Appendix G

Second Study Test 1:

Below is the test 1 given to the students. There is no time limit for completing the test. Most students finished within 8 minutes.

Name:                                   Group:

1. Check (X) all that apply: WHAT IS THIS SHAPE?

   __ It is a square                      __ It is a rhombus
   __ It is a rectangle                   __ It is a quadrilateral
   __ It is a parallelogram              __ It is a quadrilateral

2. Look at each of the following shapes. Circle ANY of the shapes that are a quadrilateral.

   1) A  B  C

      __ It is a square
      __ It is a rectangle
      __ It is a parallelogram

   2) A  B  C

      __ It is a rhombus
      __ It is a quadrilateral
3. Jack drew the shape shown below.

How many right angles does Jack’s shape seem to have? Write your answer in the line below.

________

a. Now, Draw a shape that has 4 sides but has NO right angles. Label your shape with its mathematical name.

4. Which of these shapes has exactly one pair of parallel sides?

A. 

B. 

C. 

D.
Appendix H

Second Study Test2:

Below is the test2 given to the students. There is no time limit for completing the test. Most students finished within 8 minutes.

Name:  
Group:  

1. Check (X) all that apply: WHAT IS THIS SHAPE?

   ___ It is a square  
   ___ It has right angles  
   ___ It is a parallelogram  
   ___ It is a rhombus  
   ___ It is a quadrilateral

2. Look at each of the following shapes. Circle ANY of the shapes that are a quadrilateral.

   1) A  
      B  
      C

   2) A  
      B  
      C
3. Lucy drew a square, as shown below.

How many right angles does Lucy's shape seem to have? Write your answer in the line below.

__________

a. Draw a shape that is NOT a square but has 4 sides and 4 right angles. Label your shape with its mathematical name.

1. Which of these letters has one pair of parallel sides?

A. 

B. 

C. 

D. 

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Appendix I

Second Study Pre-Survey:

Below is the pre-survey given to all the students before the experiment. There is no time limit for completing the survey. The goal of the survey is to know the students’ opinion towards math.

Name: ______________________ Age: ______ Group: ______________________

1. Compared to most of your other school subjects, how good are you in math?

   ![Smiley faces for Very poor, Poor, Middle, Good, Very good ratings]

   - Very poor
   - Poor
   - Middle
   - Good
   - Very good

2. Do you think math is an interesting major?

   ![Smiley faces for Not at all, A little bit, Middle, Interesting, Very interesting ratings]

   - Not at all
   - A little bit
   - Middle
   - Interesting
   - Very interesting

3. How good would you be at learning something new in math?

   ![Smiley faces for Very poor, Poor, Middle, Good, Very good ratings]

   - Very poor
   - Poor
   - Middle
   - Good
   - Very good

4. In general, how confident are you when solving math problem?

   ![Smiley faces for Not at all, A little bit, Middle, Confident, Very confident ratings]

   - Not at all
   - A little bit
   - Middle
   - Confident
   - Very confident

5. How much do you like math?

   ![Smiley faces for Not at all, A little bit, Middle, Like, Very like ratings]

   - Not at all
   - A little bit
   - Middle
   - Like
   - Very like
Appendix J

Second Study Post-Survey:

Below is the post-survey of the first study. There is no time limit for completing the survey. The goal of the survey is to know students' attitude towards math after playing the game.

Name: Age: Group (Game):

1. How much did you enjoy playing this game?

Not at all  A little bit  Middle  Like  Very like

2. How much you learnt by playing this game?

Not at all  A little bit  Middle  Most of  All

3. Would you play it again?

Never again  Probably not  Maybe  Probably play  Definitely

4. After playing this game, do you think math is an interesting major?

Not at all  A little bit  Middle  Interesting  Very interesting

5. How confident are you when solving math problems in the future?

Not at all  A little bit  Middle  Confident  Very confident
6. Do you prefer to learn math in the playground by playing games or sitting in the classroom taught by teachers?

- In the playground
- In the classroom

7. In the future, how good would you be at learning something new in math?

- Very poor
- Poor
- Middle
- Good
- Very good

8. After playing this game, how much do you like math?

- Not at all
- A little bit
- Middle
- Like
- Very like
Appendix K

Reference Figure:

Below is the reference figures used in the Tangram. There are two different kinds of reference figures (within inner lines and without inner lines) based on different game levels.

Easy Level:
Difficult Level: