Learning Recycling From Playing A Kinect Game

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ABSTRACT

The emergence of gesture-based computing and inexpensive gesture recognition technology such as the Kinect have opened doors for a new generation of educational games. Gesture based-based interfaces make it possible to provide user interfaces that are more nature and closer to the tasks being carried out, and helping students that learn best through movement (compared to audio and vision). For younger students, motion interfaces can stimulate development of motor skills and let students be physically active during the school day. In this article we presents an evaluation of a Kinect educational game where students learn to recycle using body gestures. The focus of the evaluation was to investigate potential advantages using gesture-interfaces in educational games, how the game affected the students' engagement, motivation and learning, and if there were any social preferences for playing the game. The results show that elementary school students get highly motivated and engaged playing a Kinect recycling game. The students also report that they learn from playing this game and prefer such game-based learning to traditional lectures. Finally, the students preferred playing this game as a multi-player game, where the boys preferred to play competitive while the girls preferred playing collaboratively.

Keywords: Gesture-based Computing, Educational Game, Game-based Learning, Kinect, Motion-based Interfaces.

1. Introduction

Games when done right are powerful learning machines, and the use of games and game technology can enhance learning (Gee, 2005). In K-12 education, games have been found to improve academic achievement, motivation and classroom dynamics (Rosas et al., 2003), and similar results have also been found in higher education (Sharples, 2000). Most existing educational games use traditional game controls such as mouse and keyboard, or gamepads. The emergence of gesture-based computing and inexpensive gesture recognition technology have opened up for experimenting with new ways of interacting in educational games (Dede, 2009). Gesture-based educational games can be beneficial in many areas. *Firstly*, it is possible to provide user interfaces that are more natural and closer to the task to be achieved (Johnson, Levine, Smith, & Stone, 2010). *Secondly*, gesture-based educational games allow students to use their body while they are playing which will reduce physical passivity. *Thirdly*, students that learn the best through physical movement get stimulated. Unfortunately, there are few educational tools and practices to support the latter. Thus it is important to also stimulate the students that learn the most through kinesthetic. *Fourthly*, gesture-based educational games opens the opportunity to learn complex phenomena through multiple perspectives and provide a foundation for situated learning with more authentic context (Dede, 2009).

This article presents a gesture-based educational game that uses Kinect to teach elementary school students recycling. In the game, the students work at a recycling plant and are responsible for moving various items of waste from a conveyor belt into the correct recycling bins by engaging pistons. The goal is for the students to place all waste correctly, as more and more waste comes down the conveyor belt that gradually runs faster. The game ends, when three items of waste have been missed. The game offers a single player, a collaborative, and a competitive game mode. The article presents the results from an evaluation of this game on an elementary school where 57 students played the game. The focus of the evaluation was to investigate the potential advantages of gesture-based educational games, to see how this game affected the students' engagement, motivation and learning, and investigate what social preferences the students had for playing the game. The data from the evaluation was collected through a questionnaire, observations and interviews.

The rest of the article is organized as follows. Section 2 presents the related work, the Kinect Recycle game, and the research methodology. Section 3 presents the results from the evaluation. Section 4 discusses the results from the evaluation. Section 5 concludes the paper.

2. Material and Method

This section presents related work, the Kinect Recycle Game, and the research goal, the research questions and the research method.

2.1 Related Work

The related work section is divided into three subsections. The first subsection focuses the motivation for gesture-based computing, the second subsection covers various usage of gesture-based interfaces, while the last subsection specifically focuses on Kinect.

2.1.1 Motivation for Gesture-based Computing

The Horizon Report lists gesture-based computing as technology to watch in 2014/2015 (Johnson et al., 2010). Most common applications for gesture-based computing are computer games, file and media browsing, and simulation and training. Gesture-based computing is also relevant for teaching and learning, and especially in the form of simulations that look, feel and operate almost exactly like their real-world counter parts. Gesture interfaces done right will make system interaction seem natural and fun, as way as it allows for new ways of collaboration (Johnson et al., 2010).

The motivation for doing gesture-based computing is to provide immersive interfaces that for example can be used to improve engagement and learning (Dede, 2009). Immersion is the subject impression that one is participating in a comprehensive, realistic experience. According to Dede, studies have shown that immersion in a digital environment can enhance education in at least two ways (Dede, 2009): *Firstly*, the user can change her/his perspective to easier understand a complex phenomenon decomposed into ***multiple perspectives***. This will typically result in a more concrete learning where the learner is in control of learning and how to approach a complex phenomenon. *Secondly*, immersive interfaces can provide ***situated learning*** that can offer more authentic contexts, activities and assessments coupled with guidance from expert modeling, mentoring, and legitimate peripheral participation. Situated learning using gesture-based interfaces is a very powerful pedagogy with a very high learning outcome.

Another good reason for bringing gesture-based computing into education is the fact that the learners are different and learn in different ways. It is believed that there are at least three primary learning modalities: auditory, visual and kinesthetic. Most learning approaches focus on auditory and visual aspects. Gesture-based learning systems can support kinesthetic pedagogical practices to benefit learners with strong bodily-kinesthetic intelligence. Gesture-based interfaces has the potential to enhance classroom interaction, to increase classroom participation, to improve teachers' ability to present and manipulate multimedia and multimodal materials, and to create opportunities for interaction and discussion (Hsu, 2011). Physical gestures have been considered a fundamental starting point for all human verbal communication, and through use of gesture interfaces we get new learning experiences that takes that into account. Some challenges of using such technology to a large scale for education have been technical challenges related to recognition of facial expressions, individual finer movement, and multiple users. Especially the latter is a problem in classroom, where a single device is not suitable for group settings (Evans, 2012).

Frameworks for supporting development of gesture-based educational systems are becoming more common. Examples of such frameworks is the game object model version II that supports gesture interfaces (Amory, 2007), an interaction educational game framework using hand gesture recognition (K. Zhang, Zhai, Leong, & Wang, 2012), and the PlayMancer serious game development framework that includes support for speech recognition, touch interface, biosensors, and motion-tracking (Conconi et al., 2008).

2.1.2 Various Use of Gesture Recognition

There are several examples in research literature on usage of gesture-based interfaces for educational or similar usage, and here is a short overview of some of them. This section covers research not related to the Microsoft Kinect device, which is covered in the following subsection.

An early use of gesture-based interfaces was within virtual reality (VR) used for education and training. VR has been used to stimulate interests in algebra, geometry, science and the humanities through immersion, and the advantage of using such technology is that the default desktop metaphor is replaced with a world metaphor. Another advantage with gesture-based interfaces in VR is that it replaces indirect manipulation of objects (using mouse and keyboard) with more direct manipulation object (using the body or parts of the body directly) (Psotka, 1995). One other example of using gesture-recognitions in education is to classifying interest in children trying to solve an educational puzzle on the computer using a camera and software to extract features from face and head gestures (Kapoor & Picard, 2005). Similarly, gesture recognition has been used to observe users using a Wiimote controller to automatically uncover the user's cultural background based on his or her gestural activities. The cultural background information extracted from this system can be used as a starting-point for user preferences in educational software (Rehm, Bee, & André, 2008).

Gesture recognition is also frequently used in robots. One example is the Robota robot, which is a toy as well as an educational tool. Gesture recognition has been used in therapy for children with autism, where Robota mirrors the movements of the arm and head of the child as long as the child look straight in the robot's face. Another example is teaching children to draw through a game where Robota recognizes postures of a stick figure drawn by the child, and reproduces the posture (Billard, 2003). Further, an interesting use of gesture recognition is the REXplorer mobile pervasive tourism game where the user can encounter the spirits of historical figures at real historic locations and buildings by waving a cell phone through the air (Ballagas, Kuntze, & Walz, 2008). In this game the gesture recognition process is supported primarily through camera-based motion recognition.

The current most successful commercial application of gesture-based interfaces has been sports games for Nintendo Wii, Microsoft Kinect, and Sony PlayStation Move (Pasch, Bianchi-Berthouze, van Dijk, & Nijholt, 2009). More novel and untraditional usage of gesture recognition include musical and dancing games (Blaine, 2005), a game to guide a virtual driver to park a virtual car into a parking lot using real gestures (Bannach et al., 2007), the use of body gestures to control *quick time events* in interactive story telling (Kistler, Sollfrank, Bee, & André, 2011), provide immersive math education for the Deaf (Adamo-Villani, Heisler, & Arns, 2007), and learning math using gestures to guide an object along the path leading to a correct answer (Thakkar, Shah, Thakkar, Joshi, & Mendjoge, 2012).

2.1.3 Use of Kinect in Gesture-based Systems

Kinect was launched on 4th of November 2010 as an add-on to Microsoft's XBOX 360 game console. With Kinect, users can interact with the game system with their body in a natural way. The key enabling technology is human body language understanding made possible through video camera technology that includes sensing the third dimension (depth) (Z. Zhang, 2012). The Kinect sensor contains a depth sensor, a color camera and a four-microphone array that provide full-body 3D motion capture, facial recognition, and voice recognition. The XBOX One game console was released in fall 2013 with a new updated Kinect device. The new Kinect uses a wide-angle time-of-flight camera, and has more powerful processing capabilities enabling higher fidelity and can track without light using an active IR sensor. The new Kinect can now track up to 6 skeletons at once. Although the Kinect was mainly intended for games on the XBOX platform, the release of the Kinect API has opened new possibilities to the use of Kinect beyond entertainment games, e.g. for teleimmersive conferencing (Z. Zhang, 2012).

Commercial Kinect games have been found to be beneficial for younger kids and found to fit well with official Kindergarten curriculum offering *Physical development* (full body movement in games such as Kinect Sports and Kinect Adventures), *Emotional development* (care for virtual pets in Kinectimals and Fantastic Pets), *Cognitive development* (challenge the brain playing games such as Body and Brain Connection and Kinect Fun Labs), and *Social development* (solve social challenges in Once upon a Monster and socialize in Avatar Kinect) (Kandroudi & Bratitsis, 2012).

Due to Kinect's ability to do full-body 3D motion capture, it has many application areas. In (Chye & Nakajima, 2012), Kinect was successfully used to teach Martial Arts for beginners through a game. Some challenges recognized for using Kinect for teaching Martial Arts were low depth resolution for far distance and speed of capturing. In (Zafrulla, Brashear, Starner, Hamilton, & Presti, 2011), Kinect was tested for potential use in a sign language recognition game. A prototype Kinect-based system was compared to the existing CopyCat system, which uses colored gloves and embedded accelerometers to track children's hand movement. The results reveal that the Kinect system requires more tuning for seated use, but in general worked very well. Kinect has also been used for physical rehabilitation and experimental results show that young adults with motor disabilities significantly increased their motivation for physical rehabilitation, thus improving exercise performance during the intervention phases (Chang, Chen, & Huang, 2011). Xdigit is an arithmetic Kinect game to enhance math learning experiences (Lee, Liu, & Zhang, 2012). In the game, the player uses gestures to identify the correct mathematical operator to complete the equation to match the target number. The motivation for the game design of Xdigit was for the student to better memorize the operators and their behavior through doing gestures that resembles the operators.

2.2 The Kinect Recycling Game

The goal for designing the *Kinect Recycling Game* was to develop a game where the player could learn about recycling in an engaging and realistic way. We wanted to create a game where the players would be so involved in the game that they did learn even without knowing it. It was important for us to find a concept that fitted well with the target audience (Callele, Neufeld, & Schneider, 2005), which in this case would be students in elementary schools. Our game design was inspired by Tom Malone's characteristics that enhance the intrinsic motivation of the player: Challenge, Fantasy, and Curiosity (Malone, 1980). Malone argues that it is very important that games have the appropriate level of *challenge* and to win the game the player must respond to the game with actions with uncertain outcome (to keep the player's attention). Further Malone argues that the best use of *fantasy* in a game is when it is in alignment the educational goal (intrinsic fantasy). For us, it meant that the player should carry out tasks in the game that would make sense in terms of recycling. The use of the Kinect should also contribute to enhance intrinsic motivation. *Curiosity* is related to stimulating the players' sensory system as well as stimulating the cognitive curiosity. The sensory curiosity is typically stimulated through exciting and inviting user-interface, which in our case also included motion gestures. The cognitive curiosity in our game can be achieved by hiding information or presenting information randomly, making the player wonder about what will come next (what is the next challenge).

In the Kinect Recycle Game, the player is asked to work on a recycling plant where to goal is to throw different type waste in the correct recycling bins. The recycling plant consists of a conveyor belt with waste, and the player can activate several pistons that will move waste from the conveyor belt into bins for plastic, paper, glass & metal, and trash only – respectively. Figure 1 shows a sketch of an early game design for the Kinect Recycle Game.

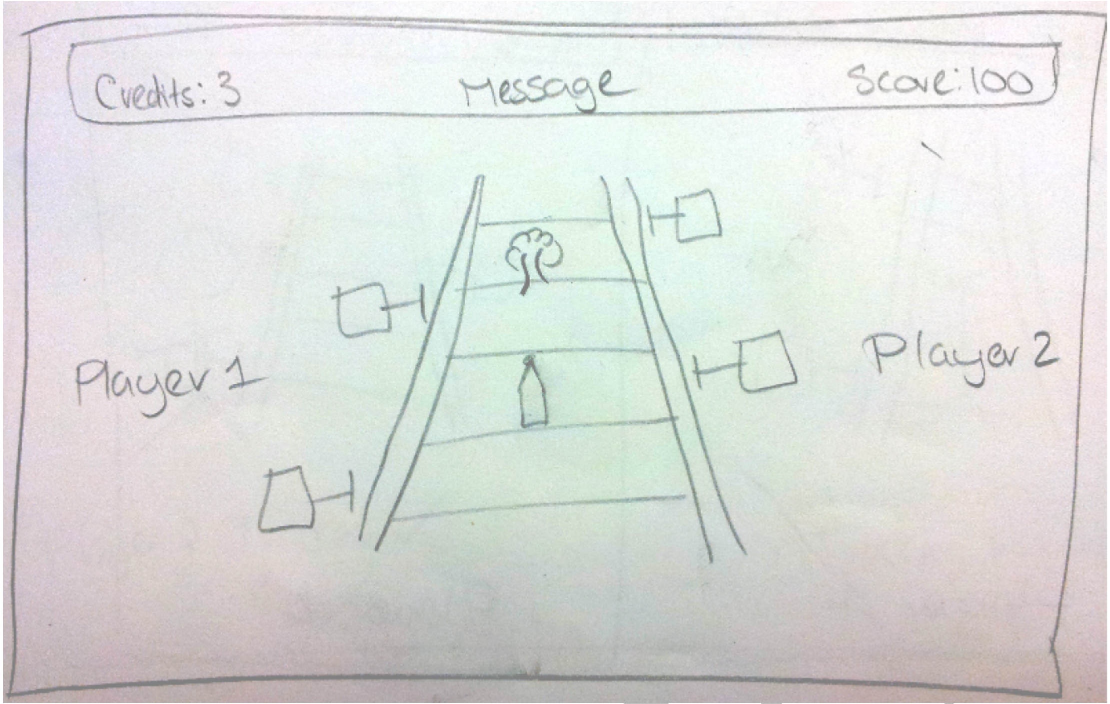

Figure 1. Sketch of the Kinect Recycle Game

The game was developed using the XNA framework from Microsoft and the first version of the Kinect was used in the prototype. The controls in the game can be carried out using hand gestures in front of the Kinect camera, an XBOX 360 controller or the keyboard. The navigation through menus was carried out as shown in Table I.

Table I. Navigation in Menus

Action	Gesture	Controller	Keyboard
Navigation	Move right arm up and down	D-pad keys	Arrow keys
Select	Swipe arm left to right	Start button	Enter key
Accept	Both arms above the head	Start button	Space key
Cancel	Arms in ‘X’ position	Back button	Escape key
Pause	Join hands	Back button	Escape key

The gameplay actions were designed to control the pistons in the game through swipe gestures of up to six different positions related to the positions of the pistons in the game. Figure 2 shows the hand gestures to control the recycling game play from upper right (a) to lower left (f).

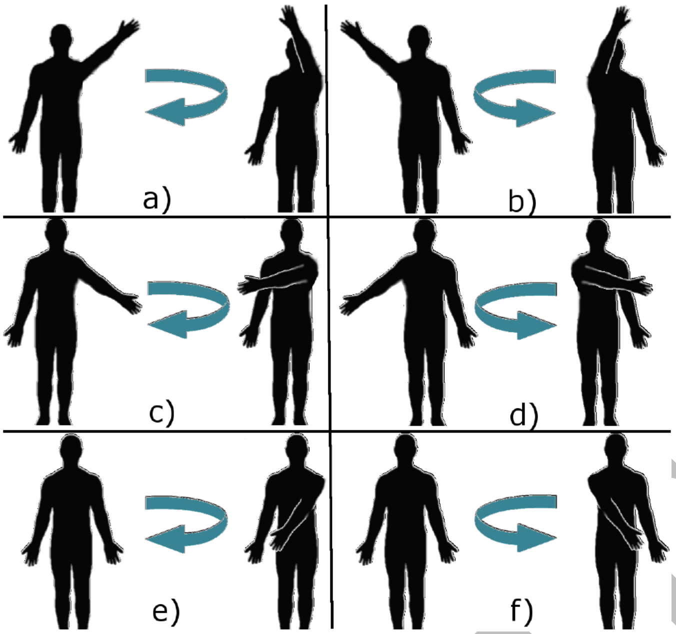

Figure 2. Hand gestures for In-game Controls of the Kinect Recycle Game

The following three game modes were implemented in the game:

- **Single player mode**: The player tries to recycle correctly as many items she or he can. New items are added for the player to recycle while the score increases over time. The longer the player recycles, the faster the conveyor belt with random items to recycle goes. The recycling bins will change their position randomly after the player has recycled a certain number of items. Bonus items can also appear on the conveyor belt. These bonus items can give extra credit, double the points, and slow down the conveyor belt.
- **Cooperative mode**: In this game mode, two players help each other by letting each player be responsible for half of the pistons on their side of the belt. The players have to cooperate and only recycle the items they are responsible of. This game mode becomes progressively more difficult as more items to be recycled are added and the speed of the belt increases. More over, at certain times, the pistons and their bins change places, so the players must pay attention so they do not end up putting waste in incorrect bins. Bonus items similar to the single player mode are also available for this game mode.
- **Versus mode**: In this two-player mode, each player has his/her own conveyor belt and is in charge of recycling his/her own waste as fast as possible. The game gets also progressively more difficult by increasing the speed and number of items. The versus mode has the same bonus items as the single player mode, and two additional ones. One bonus item let the controls for the opponent swap (mirrored controls) for a limited time. Another bonus time will randomize the recycling bins of the opponent.

For all three game modes, the game is over when all credits have ben lost. The player looses lives by putting trash in incorrect recycling bins or is not able to move an item to any bin before it falls off the conveyor belt.

2.3 The Research Goal, Questions and Methods

The research method used in this study is based on the Goal, Question, Metrics (GQM) approach where we first define a research goal (conceptual level), then define a set of research questions (operational level), and finally describe a set of metrics to answer the defined research questions (quantitative level) (Basili, 1992). The metrics used in our study is a mixture of qualitative and quantitative data.

The research goal of this study was defined as the following using the GQL template:

The purpose of this study was to *evaluate the impact on motivation, engagement and learning of a motion-based educational game* from the point of view of *an elementary school student* in the context of *teaching recycling*.

The following research questions were defined by decomposing the research goal:

- RQ1: *What are the benefits of using motion capture in educational games?* This research question investigates potential positive effects of using motion capture to control educational games.
- RQ2: *How does a motion-based educational game affect the students' motivation, engagement and learning?* This research question looks specifically on how the Kinect Recycling Game affects the motivation, engagement and learning of the students playing the game.
- RQ3: *What are the players' social preferences for motion-based educational games?* This research question investigates whether the students playing motion-based educational games prefer to play single-player, competitive or collaborative.

Table II presents a summary of the data sources, metrics and the comparison methods used in this study.

Table II. Summary of Data Sources, Metrics, and Comparison Methods

RQs	Data Sources	Metrics	Comparison Methods
RQ1	Survey, Observations, Literature study	3-level Likert Scale [Disagree, Neutral, Agree], Observations	Percentwise distribution, comparison of observations
RQ2	Survey, Observations, Interviews	3-level Likert Scale [Disagree, Neutral, Agree], Observations, Interview responses	Percentwise distribution, comparison of observations
RQ3	Survey, Observations, Interviews	3-level Likert Scale [Disagree, Neutral, Agree], Observations, Interview responses	Percentwise distribution, comparison of observations

The data sources used to evaluate the research questions consisted of observations from students playing the game, interviews, and a questionnaire conducted after the students had tried out the game. To test the game in an appropriate environment, we decided to let students in an elementary school play the recycle game. The test process was the following:

1. Short introduction to the game and the game controls
2. Let one or two students play the game (single-player or multi-player), while observing
3. Students fill out a questionnaire on how it was to play the game
4. Interview a selection of students

The questionnaire consisted of four main parts:

- Demographics of the student: Age, gender, exposure to video games, exposure to motion-based video games

- Statements regarding students' perception of playing the game: 10 statements where students could choose to disagree, neutral or agree
- Preferred game-mode: Single-player, competitive, collaborative, none
- Rate the initial difficulty level and progress of difficulty in the game

3. Results

This section describes the results from the evaluation of the Kinect Recycle game, and is divided into quantitative results, feedback from student interviews, and observations.

3.1 Results from the Questionnaire

The evaluation of the Kinect Recycle Game took place May 24th 2013 at Buvika Elementary School in Norway from 09:00am to 3:30pm. The research group consisted of the authors of the article, and the participants were students from 6th grade as well as volunteer students in an after school program at the school. The demographics of the participants are shown in Figure 3. 57 subjects participated in the evaluation where the gender distribution was 49% boys and 51% girls. 66% of the participants were 6th graders, and the rest came from the after school program with the following distribution: 16% 3rd graders, 16% 2nd graders, and 2% 1st graders.

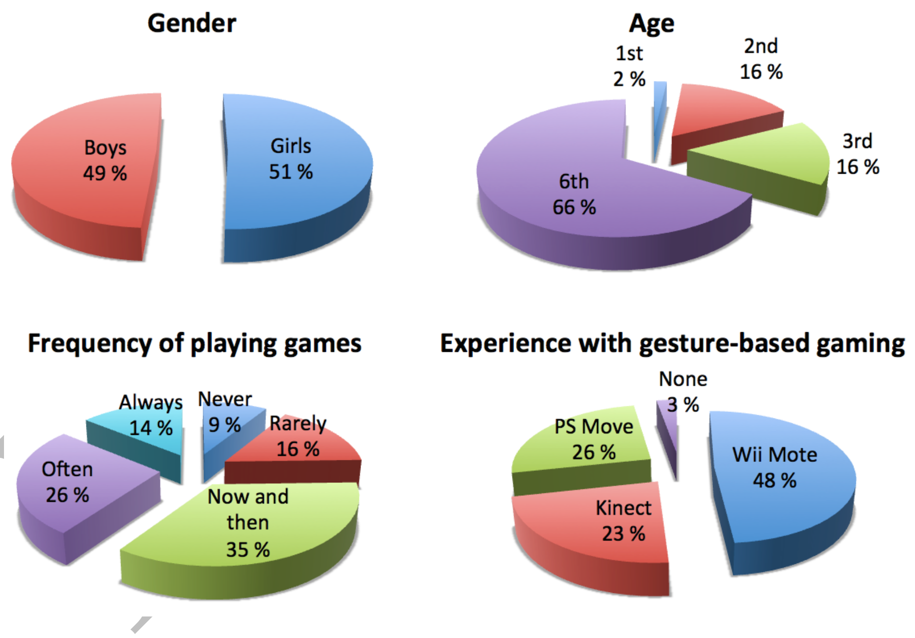

Figure 3. Demographics of the participants in the study

Only 9% of the students said they never play video games, 16% rarely, 35% now and then, 26% often, and 14% always. The majority of the students played video games at least a couple of times a week, and 40% play everyday. We also asked about the students' prior experience of gesture-based gaming. Only 3% of the students had never played a gesture-based game. Close to half of the students had played games on Nintendo Wii, and around a quarter of the students had played games using the PlayStation Move or the Microsoft Kinect. Note that many students had played games on more than one gesture-based game platform.

The results from the questionnaire about learning, motivation, enjoyment, and usability are shown in Figure 4. The first three statements (1-3) in the questionnaire focused on *learning*. In the first statement, 86% of the students said they learned recycling from playing the game, where 7% said they did not learn anything from playing the game. 81% of the students said that it was easier to recycle in real life after playing the game. For the third statement, the students responded a bit more reluctant to whether they would recycle at home after playing the game. However, 65% of the students said they would recycle at home after playing the game. Some of these students said that they were already recycling at home.

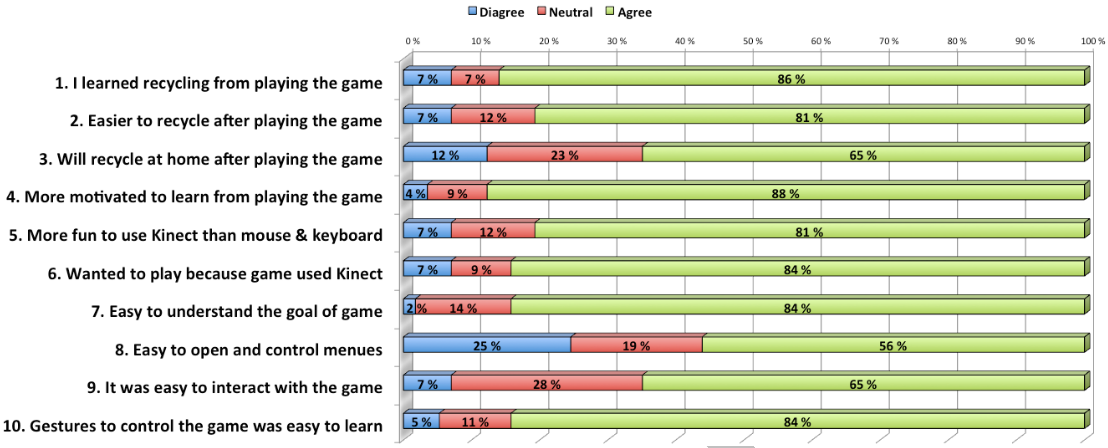

Figure 4. Results From the Questionnaire

The statements 4-6 focused on *motivation*. In statement 4, 88% of the students said that they were more motivated to learn (about recycling) from playing the game. In the questionnaire we also asked whether the students preferred to learn about recycling through playing a game or as a part of a lecture. 82% of the students preferred to learn about recycling through a game vs. 18% preferred lecture. The majority of the students (81%) thought it was more fun to use Kinect to control the game than using mouse and keyboard (statement 5). Similarly, 84% wanted to try the game because it used Kinect.

The last four statements focused on the *usability* of the recycle game. The majority of the students (84%) said it was easy to understand the goal of the game. However, only about half of the students (56%) thought it was easy to navigate through the menus of the game using hand gestures, and 25% of the students disagreed to this statement. The researchers' observations also acknowledged that some students had problems navigating through the menus using hand gestures. Statement 9 asked about how the students perceived the interaction in the game (using hand gestures). 65% of the students said it was easy, while 7% said it was difficult. For statement 10, 84% of the students said that it was easy to learn the gestures necessary to control the game. Only 5% of the students found it difficult.

Figure 5 shows the preferred game modes among boys and girls. The chart clearly shows that multi-player game modes were preferred by both genders (83% by boys and 86% by girls). The chart also reveals that girls to a larger degree preferred cooperative game mode, while boys preferred the competitive versus game mode. Further, none of the girls and only 10% of the boys preferred single player.

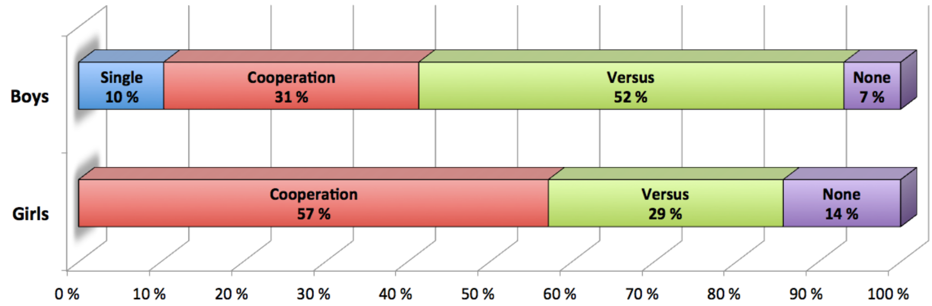

Figure 5. Preferred Game Mode

Figure 6 shows the results from the questionnaire on the difficulty of the game. Statement 11 and 12 indicate that the difficulty level of the game was appropriate. Around half of the students through the game had appropriate initial difficulty level (44%), and over half of the students thought the program had appropriate progress in difficulty (56%). However, statement 13 shows that 39% thought it was hard to distinguish between the various objects to be recycled in the game.

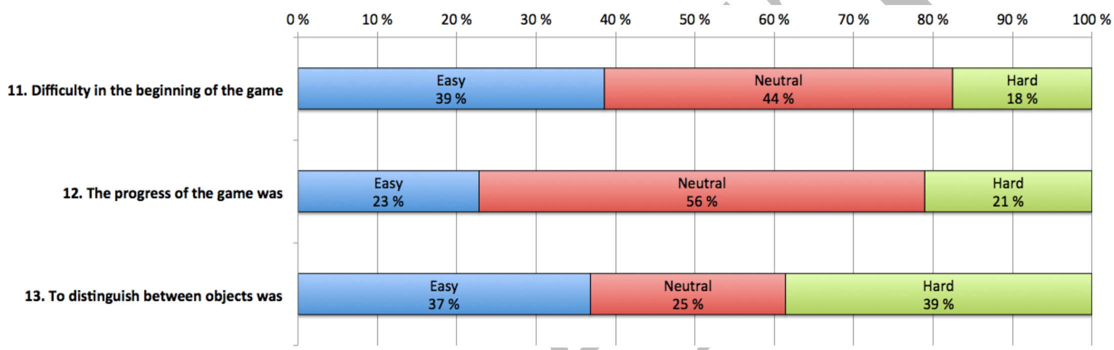

Figure 6. Evaluation of Difficulty

The final section of the questionnaire was devoted to game audio and graphics. 93% of the students thought the graphics in the game were good, and 82% thought the audio was good.

3.2 Feedback From Student Interviews

Here are some quotes from interviews of students regarding learning, enjoyment, reusability of game concept, motion capture, and social aspects.

Question: “What was good about learning through the use of a video game?”

- “If it is like this learning video game, then I think it is really fun to play and learn something new. So, one does not only listen to what some persons say about it.”
- “It is easier to learn something by doing it, like for example in a game, than being sitting with a book and writing.”

Question: “What things were fun to do in this recycling game?”

- “That I can do this with the hands instead of sitting in front of the computer”
- “That it went faster”
- “In the beginning it was quite easy, and then it went just faster and faster, and you had to concentrate.”

Question: “What would you change to make the game more entertaining?”

- “Maybe there should have been a bit more things that came more often”
- “More things like for example watermelon and fruit. More variation. And a little more bonus things to make it more difficult for the opponent.”
- “Maybe to simplify the controls because sometimes you had to twist your hand.”

Question: ”In what other areas do you think this game concept could have been used?”

- “You could have used the same game concept in math. For example, if you had multiplications of five, and the had a box where the answers were given, and then do exactly the same and push the equation in the trashcan.”
- “In religion, you could have place different words in e.g. Christianity, and in other religions.”

Question: “What is your opinion of using Kinect in this game?”

- “I think it was a lot of fun when you have to move instead of being seated and pressing the keyboard or holding a controller”
- “Very cool!”
- “I think it was brilliant!”

3.3 Observations

Some technical difficulties were observed during the evaluation of the game. The most critical technical difficulty was that the Kinect device was not working correctly all the time. The game sometimes recognized movements incorrectly and started to randomly move game elements. It was noticed that this situation occurred sometimes because the players moved from the horizontal range of the camera and stopped being tracked, and then the Kinect device started tracking other students outside the room looking through a glass door. This problem was solved by placing a whiteboard in the room in front of the glass door. We also noticed a problem that some students had difficulty recognizing what the graphical objects to be recycled on the screen illustrated (like a plastic cup). We found that the problem was related to the limited contrast of the video projector in the room, and was fixed by adjusting the contrast to maximum. Another recurring problem was that some students kept pausing the game by joining their hands. Even this pause interrupted the game play, the students did not seem to mind this problem too much and just carried on playing the game.

In the beginning of the evaluation, the researchers demonstrated to the kids how the game should be played. Most kids used a couple of minutes to get familiarized with the hand gestures, but soon mastered the controls. Later on we invited students waiting in line to watch other students play the game, and in this way learning the gestures. This was a much better and more efficient approach that worked very well. Figure 7 shows pictures from kids playing the Kinect Recycling Game.

Figure 7. Pictures from kids playing the Kinect Recycling Game

The kids were a bit shy and embarrassed about performing the movements needed to play the game in single player mode front of others in the beginning, but after a couple minutes they only focused on the game and to do their best in recycling trash. While playing, engaged students were shouting out phrases such as “oh no!”, and “it is not working” when they missed an item. Many students asked if they could play again. One of the students asked if it was possible to buy the game at GameStop. He said, “this is the best game I have ever played!”

After having a good number of students playing the single player mode, we started to test the versus and the cooperative mode. More girls preferred the cooperative mode, while more boys preferred the competitive versus mode. The kids that were playing the cooperative game mode, continuously reminded each other on paying attention to what was going on in the game. The other kids watching a game where helping the players out by identifying the items in the game by saying “That is a bag”, “it’s plastic, plastic!”, and “Milk carton, so it’s paper!”

The students that played the competitive versus mode were very engaged, and paid close attention not to miss any items. The students seamed to be happy about competing and especially the students that won over a fellow student.

Figure 8. Interview after Playing the Game

After the students had played the game, a form was filled out as well some students got interviewed. Figure 8 shows a picture of two 6th graders being interviewed. Most students were very happy about getting the chance to play a game that was actually teaching them recycling, and also happy about filling out questionnaires and answering answer in an interview. The students were pleased that they could contribute to research on game-based learning.

4. Discussion

In this section, the results of the evaluation will be discussed in the light of the three research questions defined in Section 2.1.

RQ1: *What are the benefits of using motion capture in educational games?*

The results from the questionnaire shown in Figure 4 showed that 81% of the students thought it was more fun to control the game using Kinect compared to using mouse & keyboard. The fact that most educational games are based on mouse and keyboard input and this is what students expect from such games, can make an educational game using motion capture more exciting to the students. Observations of students playing traditional vs. gesture-based education games confirm this statement. Another benefit from using motion caption controls is that it will improve the players' spatial, visual and psycho-motor skills (De Aguilera & Mendiz, 2003). Motion capture controls in games have successfully been used to improve visual perception processing, postural control and functional mobility of adolescent with cerebral palsy (Deutsch, Borbely, Filler, Huhn, & Guarrera-Bowlby, 2008). One obvious benefit of using motion controlled educational games for younger students is it promotes being physically active at school. Not only is this good for developing motor skills, but it can also contribute to avoiding physically passive students (Yang & Foley, 2011). Finally, motion-based controls can provide more natural user interfaces in educational games and applications (Boulos et al., 2011). In our case, it is much closer to reality to learn to recycle garbage by "throwing" various items in correct corresponding recycle bins compared to using a game controller, a mouse or the keyboard. Our hope was that if we could make recycling fun, the positive experience also could be transferred to doing recycling at home. The results from the questionnaire showed that 65% said that they would recycle at home after playing the game. Between 10 and 20% of these students mentioned that they were already recycling at home before they played the game.

If designed right, motion-based educational games have the same benefits as other serious games as well as they can provide a more natural user interface that can provide learning that is closer to the real thing. It is important to research the various domains in which such game technology can be used, and study the effects for various domains.

RQ2: *How does a motion-based educational game affect the students' motivation, engagement and learning?*

The interviews, the observations and the results from the questionnaire all points in the same direction that motion-based educational games can positively affect the students' motivation, engagement and learning. Even before the students got to try the game, the students were very curious and excited about playing an educational game with motion control. Close to all students (88%) said they were motivated to learn about recycling from playing the game. The observations gave a clear indication that the students were very focused and engaged while playing the game, as well as when they were watching fellow students playing the game. Only a couple of students were reserved about playing the game, and had to be motivated to start playing. But as they got into the game, they were all engaged and motivated. The recycle game fits well into the category Malone defines as a good and motivating learning environment: The fantasy is intrinsic (in alignment with what you should learn), the curiosity is stimulated through graphics, audio and gestures, and the challenge depends on how the player performs in the game (Malone, 1980).

We did not have any formal tests to assess how much more the students had learned about recycling from playing the game. Their own assessment concluded that 86% of them had learned recycling from playing the game, and 81% said it was easier to recycle after playing the game. To maximize learning and make learning fun, it is important that the difficulty level of a game is appropriate (Malone, 1980). The results from the questionnaire showed that the initial difficulty level of the game and the progress in difficulty of the game was appropriate for most students. An improvement could be to provide a choice of difficulty level from easy, normal to hard – to better support the variation in the student group.

Apart from making learning fun, games can provide a learning-centered environment where users can form their own concepts instead of trying to memorize what the teacher says like in traditional lectures [54]. This learning-centered environment was observed during the evaluation of the game, where the students instead of waiting for someone to tell them in which recycle bin each item should go, they started to form their own knowledge by classifying the item and depositing it into the correct recycle bin.

RQ3: *What are the players' social preferences for motion-based educational games?*

The results from the survey clearly showed that most students preferred the social game modes. Only 10% of the boys preferred the single player mode (none of the girls). The results from our evaluation clearly showed that girls to a larger extent preferred the cooperative game mode, while boys preferred the competitive one. The interview revealed that students that focused on winning enjoyed the competitive game mode the best, while students that thought it was more fun to help fellow students preferred the collaborative game mode. Other students said they preferred the collaborative game mode because they did not like to loose, they felt better about sharing the responsibility of recycling the garbage, or they felt uncertain about their own skills. Several mentioned that they preferred to play one of the multiplayer game modes as it was more social and it resulted in a more entertaining experience. During the test, we observed some girls that did not dare to play the game until they could play it collaboratively with a friend. Our conclusion is that it is important to provide a variety of game modes for such educational games, and especially a collaborative game mode that will lower the risk for excluding girls and students that are less confident about their own skills. Another benefit we observed with the collaborative game mode was that students learn while they are helping each other. If a student was uncertain about which bin an object should be thrown in, the fellow student would assist and teach the other student. In terms of engagement, our observations concluded that the competitive game mode had the highest, collaborative the second highest, and the single player had the lowest engagement level.

5. Conclusion

In this article we have presented an evaluation of an educational game that uses Kinect for teaching students about recycling. The player uses hand gestures to throw various objects into recycling bins. The game has a single player, a collaborative, and a competitive game mode. The evaluation of the game was carried out at an elementary school where 57 students participated with an even gender distribution, and where most of the students were 6th graders.

The focus of the evaluation was to find answer to three research questions. In the *first research question* we wanted to investigate the benefits of using motion controls in an educational game. We found that the students preferred controlling the game using body gestures compared to conventional user interfaces. The use of gesture-based interface provided an engaging and motivating learning environment. A benefit specifically for our recycling game was that motion controls gave a more natural user interface closer to real-life recycling compared to using conventional game controls. Another benefit with motion-controlled games is that gives the students an opportunity to physically move while learning, which is not always the case with traditional learning approaches. Finally, motion control can help especially younger student to develop better motor skills.

The *second research question* asked how a motion-based educational game affects the students' motivation, engagement and learning. Based on the results from our questionnaire, observations and interviews, we found that such games will boost the students' motivation and engagement, and especially in multiplayer game modes. Although we were not able to measure the learning effect in our study, the students perceived that they learn better with the game than other approaches. Not only did the student believe they learned more about recycling, but most of the students also said they would start to recycle at home. We observed situated learning where students guided and helped other students to find the right solution in context of the being in the middle of the problem.

The *third research questions* asked whether the students had any social preferences for what game mode to play. We found that the large majority of the students preferred multiplayer game modes. Only 10% of the boys preferred single player mode. We also found that boys to a larger extend preferred competitive while girls preferred collaborative game play.

We were overwhelmed by the positive feedback from the students regarding the Kinect Recycling game. Even though the graphics and audio was simple and there were some issues related to incorrect gesture recognition, the kids really enjoyed playing this educational game and said that they preferred using gesture controls and learning through similar games. Future work will include the creation and experimentation with new prototypes to test out motion-based gaming in other educational domains.

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