THE EFFECTIVENESS OF PAIRING ANALOG AND DIGITAL GAMES TO TEACH COMPUTER SCIENCE PRINCIPLES TO FEMALE YOUTH

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ABSTRACT

Computer science and its related fields are rapidly growing. However, there is a significant and rising shortage of women in this career domain. To combat this shortage, we explored the potential of coupling analog and digital games teaching computer science concepts to educate, interest, and engage female youth. For our purposes we created and used an analog and digital game both teaching the same computer science principle, image representation, in an after school program setting with middle school-aged females. Assessments were completed by the girls before and after the analog game version to compare what participants already knew to what they had learned through the analog game play. Vital game play statistics were also recorded from the digital game to assess if further engagement or applied learning took place. The observations, assessments, and statistics gathered were evaluated to determine whether or not analog and digital games teaching computer science principles combined together can provide an engaging and enriching educational experience.

INTRODUCTION AND BACKGROUND

Games have been shown to be useful tools in teaching educational materials to adolescents [6]. Educational games have been used for many decades both inside and outside the classrooms due to their success in teaching educational concepts. They can provide entertaining and immersive environments that allow for the student to enjoy learning and want to continue playing and learning [6]. Video games can be considered a valuable tool in learning and education when used appropriately [3]. In recent years, many education researchers have begun looking into various elements of games for education to determine what other variables can contribute to or hinder learning and engagement. Some of these variables researchers are focusing on are games with story, context, abstract content and whether or not they have any impact on student learning [4]. Other researchers are more focused on gender issues, with their research targeting female audiences. They investigate factors, such as cooperative play, that can further contribute to influencing, engaging, and educating adolescent girls [2].

With the number of women in the computer science fields drastically dropping [2,5], finding methods to influence more women to join the computer sciences is of growing importance. To increase [1] the number of women in computer science, we

must start by focusing our attention on educating and engaging girls today [7]. This study explores the prospect of combining the use of a digital and analog game that teaches a computer science principle, image representation, in order to engage, interest, and educate our target audience in a more enriching and well-rounded way. These two games (described in study section) are not only in different media formats, they also have different features and factors. The analog game is a cooperative and competitive paper based game played with story and without. The digital game is a single player game with player versus themselves and the clock while utilizing colors and graphics geared toward girls. By embracing these differences we have a broader reach in appealing to and educating female youth. The game play statistics gathered from the digital game play are compared to improvement statistics generated from the pre and post assessment results from the analog version of this game. The expectation was that the digital game used would be useful in engaging the participants as an extension of the analog game. The students have expanded their learning from the analog version of this game due to the digital game's engaging nature and encouragement of image representation concept repetition. We believe that the analog game version will be successful in both engaging and teaching the image representation to the female participants. Our study shows that the culmination of both the analog and digital game used together will provide a more complete educational experience for adolescent females.

STUDY

This study was conducted to explore whether the games we created to teach a computer science concept, used in combination, can be useful in educating and engaging middle school aged girls with the goal of providing them with an enjoyable experience that would increase their understanding and help them develop a positive stance towards computer science. In this research study we hope to answer several important questions:

1. How does girls' understanding of image representation change after playing the analog game?
2. What levels of engagement did girls report after playing the analog game?
3. How successful were girls in mastering the digital game?
4. How engaged were the girls with the digital game?

The two games used, both teaching the same computer science concept of image representation, were created, used, and tested in an eight week after school program called Girls Play 2 Learn. This after school program was held at the Grace Wilday Junior High School located in Roselle NJ. The participants of the after school program all attend that same school and are all middle school girls between the ages 12-14.

Analog Version - Image Representation Game

The analog game version is called the Image Representation Game. The Image Representation Game was developed cooperatively by our New Jersey and Arizona research teams under a grant from the National Science Foundation. This game was designed to be a cooperative/competitive multiplayer game in which participants work together and against one another in pairs. This game was created with story

and abstract versions. The participants were divided into two different rooms, where they either played the abstract or story analog game version. Participants and facilitators were placed in the same rooms for both game play sessions to keep consistency. The games teach the general computer science principle of how images can be represented in different ways, as well as the strategy of and run-length encoding.

The Image Representation Game was played in three levels. In the first level, each player has their opponent's image that is encoded in 0's and 1's in an 8X8 grid (0's representing white and 1's representing black). The player's objective is to reveal their own image before their opponents does. The second level of the game involves pairs of girls decoding rows of numbers into an image using a different type of run-length encoding protocol. The third level is the reverse of the second, having the player pairs encode a given image. The objective of the second and third level is to figure out the meaning of the new encoding and to decode or encode the image as fast and concisely as possible.

The Image Representation Game was played and data was collected during the first two sessions of the after school program. There were 19 participants in the first session and 23 participants in the second session. The data used in this study was collected from the pre and post-game assessments the participants filled out. The assessments were taken once before the game was played and then once after the last game was played in order to see what the participants may have learned compared to what they already knew.

Digital Version - Hidden Image Game

The digital game is called the Hidden Image Game, and it was modeled after the first two levels of the Image Representation Game developed by the whole research team. The digital game was modified to be a single player game with player versus the clock and herself. Its analog counterpart being one player versus player level and two collaborative levels. This digital game version had no story and was played in its abstract form. The game applies the concept run-length encoding as well as decoding rows of numbers to an image in two separate levels. The Hidden Image Game was developed collaboratively by Kean University undergraduate Computer Science students Stephanie Eordanidis and Miatri Chakraborty.

The variables and data collected from participants after each of their game play were:

1. Participant id numbers entered at the beginning of the game
2. The time and date of each game level when played
3. The difficulty level they chose
4. The random image that was being used
5. Time remaining on the clock
6. Total move count - level one only
7. Black spaces remaining - level one only
8. Total points - level two only
9. Last image guess made - level two

The digital game results from this study were collected during game play at the last session of the after school program. There were 18 participants in total, all of whom had already played the analog Image Representation game. Move count showed how

efficiently players utilized runs. Having zero black spaces remaining means the player finished revealing the image before the timer ran out. The time remaining showed improvement from subsequent game play. High points showed participants understood decoding. These variables were used as indicators that the girls understood the concepts that were taught to them through the analog game play weeks prior. To ascertain engagement, we looked at time taken to play levels, voluntary difficulty settings chosen by players, as well as how many games the girls played of each level to determine their engagement during the digital game play

The Assessments and Surveys

We utilized demographic and engagement surveys to determine the participant engagement level after playing the analog game. The pre and post assessments used had eight questions related to the topic of image representation. The questions used were the same between the pre and post assessment, however the specific data and answers were different to prevent the participants from memorizing answers.

RESULTS

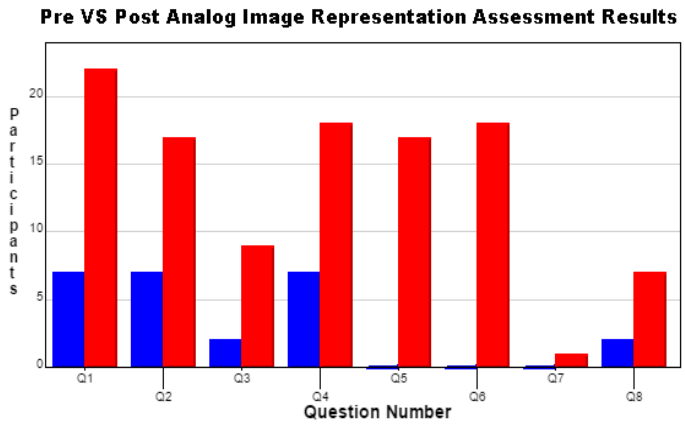

FIGURE 1 – Bars represent complete correct responses by participants

pre-game assessment results

post-game assessment results.

PRE & POST ANALOG IMAGE GAME ASSESSMENT RESULTS - FIGURE 2 - Were the participants able to correctly :

Q#	PRE	POST	Questions - meaning and purpose of question
Q1	36.8%	95.6%	match a given binary encoding to its matching image?
Q2	36.8%	73.9%	define what encoding means?
Q3	10.5%	39.1%	define what run encoding means?
Q4	36.8%	78.2%	fill in the two missing lines of binary encoding when given its matching image?
Q5	0.0%	73.9%	fill in the rest of an incomplete image when given its matching condensed encoding?
Q6	0.0%	78.2%	complete the condensed encoding when given its matching image?
Q7	0.0%	0.04%	complete an image given stream encoding using a different encoding protocol?
Q8	10.5%	30.4%	identify how much shorter the condenced encoding for a given image was compared to its binary encoding form?

Figures 1 and 2 above represent the pre and post game assessment results in a bar graph and percentages. The analog Image Representation game has shown a drastic learning improvement from pre to post for questions 1-6 (Fig. 2).

ANALOG IMAGE GAME ENGAGEMENT RESULTS - FIGURE 3				
Question	% Answered Somewhat	% Answered Mostly	% Answered Very Much	Total %
Did you enjoy what you where doing?	~ 17.3 %	~ 17.3 %	~ 56.5%	~ 95.6%
Did you find the activity interesting?	~ 17.3 %	~ 30.4 %	~ 47.8%	~ 95.6%
How well were you concentrating?	~ 21.7 %	~ 34.7%	~ 39.1%	~ 95.6%

Figure 3 shows the engagement levels of the participants when asked if they enjoyed the activity, found it interesting, and how well they were concentrating. Overall an estimated 95.6% positive feedback was reported by the participants. Figure 3 demonstrates the participants enjoyed and found the activity interesting. The participants were also able to concentrate on the task at hand very well.

DIGITAL HIDDEN IMAGE GAME LEARNING RESULTS - FIGURE 4		
Question	% Participants	Total Participants
How many participants completed level one in less than one minute?	94.44%	17
How many participants completed level one with a move count of 45 or less?	100%	18
How many participants completed level one with a low move count of 35 or less?	61.10%	11
How many participants completed level two in less than two minutes?	50%	9
How many participants completed level two with at least 48 points?	77.70%	14
How many participants completed level two with at least 56 points?	72.20%	13
How many participants completed level two with at least 64 points?	72.20%	13
How many participants completed level two with at least 72points?	55.50%	10

Figure 4 shows the game play results from the digital Hidden Image game. These questions were formulated to determine if the participants were able to apply what they had learned through the analog game play in the first two weeks of the after school program. The findings show that high percentages of the participants were successful in game and showed signs of continued learning. In addition a stunning 55.5 % of the participants earned a perfect score in the second level.

DIGITAL HIDDEN IMAGE GAME ENGAGEMENT RESULTS - FIGURE 5		
Question	% Participants	Total Participants
Did participants play or attempt mutliple games in level one?	100%	18
Did participants play or attempt mutliple games in level two?	94.40%	17
Did participants play or attempt multiple games on higher difficulty settings in level one?	88.80%	16
Did participants play or attempt multiple games on higher difficulty settings in level two?	88.80%	16
Did the participants complete multiple games in level one?	100%	18
Did participants complete multiple games on higher difficulty settings in level one?	88.80%	16
Did the participants complete multiple games in level two?	83.30%	15
Did participants complete multiple games on higher difficulty settings in level two?	66.66%	12

Figure 5 shows the engagement levels of the participants during the digital Hidden Image game play. Based on the questions formulated (shown in Figure 5), we can conclude that the digital game was very engaging to the participants. 88.8% of the participants chose to play multiple games in each level and on higher difficulty settings. The results in Figure 5 show the players enjoyed playing and wanted to play many games in each level while also challenging themselves with higher difficulty settings.

CONCLUSION

We wanted to know if educational games of both digital and non-digital nature teaching the same computer science concept, used in conjunction, could educate and engage female youth. We held a voluntary after school program with middle school girls and found that the analog game version showed the girls had an increased understanding of the computer science concept, image representation, after playing the game. The digital game engaged the participants through voluntary repetition of the game concepts and demonstrated the girls substantially reinforced the information they had learned from the first two weeks, which easily could have been forgotten by the eight week when they played the digital game. Utilizing the analog and digital games together can provide a more enriched and fuller educational experience than games or lessons on their own.

FUTURE WORK

Future research on a larger scale, and expanding to other games and computer science concepts, could show more conclusively the educational or supplemental potential for digital game accompaniment to its analog counterpart. Improvement of the analog and digital game design, using player feedback to make the game more appealing visually and engaging game play wise to be more suited to our female audience, may prove to yield more definitive results. These games and designs will be shared in teacher workshops to enable other educators to encourage and engage their students in the computer sciences.

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