Learning Math with Farmer Alfred – A Learning Game on a Multitouch Table

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Abstract: Earlier research has shown that playing games can enhance learning motivation and outcome. Tabletop interfaces provide users with natural and intuitive interactions compared with traditional interfaces. This paper presents a mathematics learning game on a multitouch tabletop. Two user tests were conducted to study the game design and to investigate the learning experience. The results indicate that the tabletop learning game provides a better learning experience than when it is played on a traditional desktop computer. Although no clear conclusion can be drawn on learning outcome, observations and informal conversations with children and their parents seem to suggest that children are more engaged and motivated in the tabletop game.

Keywords: Learning game, multitouch tabletop, math, game flow.

Introduction

The multitouch tabletop interface is a relatively new paradigm in human-computer interaction. It is one of the post-WIMP (Window, Icon, Menu and Pointer) technologies that provides a shared interface to support interaction among co-located users. Post-WIMP interfaces are considered to be more natural and intuitive than traditional WIMP interfaces. Such technologies provide more opportunities for flexible collaboration compared with traditional WIMP interfaces by allowing face-to-face interaction and multiple simultaneous inputs from several users. Studies have shown that users find it more comfortable to work together, hence engaging in more communication and participation around a multitouch tabletop as compared to sitting in front of a PC or standing in a line in front of a vertical display [19].

Previous research shows that tabletop applications are enjoyable to use [4], promote playfulness [12], support awareness [8], encourage equity of participation [6], and can promote learning [7, 9, 16]. Tabletop interfaces are also compared with other interaction mechanisms, such as with desktop computers [4], vertical displays [19], non-digital materials [16], or a different tabletop interface [6, 18]. However, there has not been any research directly comparing the learning experience of a multitouch table with that of a traditional WIMP interface. We argue that this comparison is important in understanding the affordance of tabletop-based learning applications and their effects.

In this research, we developed a tabletop learning game called "Learning Math with Farmer Alfred" for children aged 6–7 to learn mathematics. The game covers three main themes: counting, sorting and plus and minus, all with different levels of difficulty. Game design principles such as fantasy, challenge and curiosity were taken into consideration during the game design [11].

We conducted two user tests with improvement in-between based on the feedback from the first test. In the first test, we compared the tabletop game with its WIMP version using an adapted GameFlow model [21], focusing on game enjoyment. In the second test, three children aged 6–7 played the tabletop game and took a pre- and post-test on a set of mathematical problems.

1. Background

1.1 Learning Games

Earlier research suggests that games have the possibility to help students learn in an authentic, intellectually engaging way [5]. According to Prensky [17], games "give us enjoyment and pleasure; give us intense and passionate involvement; give us structure; give us motivation; give us flow; give us learning; give us ego gratification; give us adrenaline; give us social groups; give us emotion; and spark our creativity." Learning by play and active involvement leads to productive learning and long-term gain.

Today's children are digital natives, and computers have become extensions of the younger generation's lives [17]. According to a survey done in the United States, 51% of primary and secondary school students reported that gaming makes it easier to understand difficult concepts; 46% of students responded that they wanted to learn more about a topic if the information was presented as part of a game; and 44% responded that games could make it more interesting to practice problem solving. One-third of the students surveyed reported that the use of games in school could help them learn to work in groups and see the direct results of problem solving activities [14]. Many teachers were also positive about using games in the classroom. In fact, 65% of the teachers surveyed believed that learning-oriented gameplay would be an effective tool for students with different learning needs and would make students more engaged in school work. It was found that at the time of the study, only 11% of the teachers surveyed were already using games in their teaching [14].

1.2 Tabletop Learning Games

The affordance of tabletop technology has inspired researchers to explore their potential for educational purposes [3]. Educational games on tabletops such as MatchingTable, PoetryTable [20], ClassificationTable [13], Digital Mysteries [9], and Futura [1] have been developed to support collaborative learning. Tabletop learning games have also been used for children with special needs. Piper & Hollan [16] and Battocchi et al. [2] developed collaboration games on multitouch tabletops to train social skills to children with autism. Many researches on tabletop learning games [1, 10, 15] focus solely on game design issues such as design process, principles and heuristics. Some focus on the interaction and learning aspects by considering the game mainly as a learning application while ignoring the game's aspects.

2. Learning Math with Farmer Alfred

There are quite a few existing online math games for Norwegian children, but many of them have poor usability and do not specify which age group they are targeting. In the beginning of the project, we studied two main online math learning games, Multi and Lokus123, which were based on Norwegian math textbooks. The results provide a

foundation for the requirements of the multitouch table game. “Learning Math with Farmer Alfred” was designed according to the learning goals for the first class in the government’s Guidance to Teaching Plan. These goals are:

- General keywords: play, make, do and talk.
- Math in everyday life: rules in playing and gaming, arrange, count, classify, evaluate size, time phrases.
- Number: total, order, symbols, prepare for counting.
- Space and shape: make shapes and figures in two and three dimensions, move, length, area and space.

According to Malone [11], three characteristics are essential to game design: challenge, fantasy and curiosity. We took these three characteristics into consideration when designing the game. For example, we decided that the game would be situated on a farm with different animals, which children often think of as fun and exciting. One of their tasks was to help Farmer Alfred put the right number of (correct) animals (pigs, calves and sheep) into their respective pens. There were classification tasks as well as counting and plus/minus tasks (Figure 1). These tasks were organized into levels of increasing difficulty. In addition, we provided both audio and visual feedback to make the game more fun and engaging. For example, when a new level began, a rooster would crow to mark the beginning of a new day in the farm. Farmer Alfred had different facial expressions (Figure 2) which appeared in different situations, such as when the children completed a task correctly or incorrectly. The facial expressions were also associated with audio feedback. For example, Alfred would say, “Nei, dette ble ikkje helt riktig. Prøv igjen, dette klarar dåkkar!” (“No, this is not quite right. Try again, you can do it!” in a dialect from west Norway where there are many farms). This constructive feedback encouraged the children to continue playing, thus making their experience more fun and engaging.

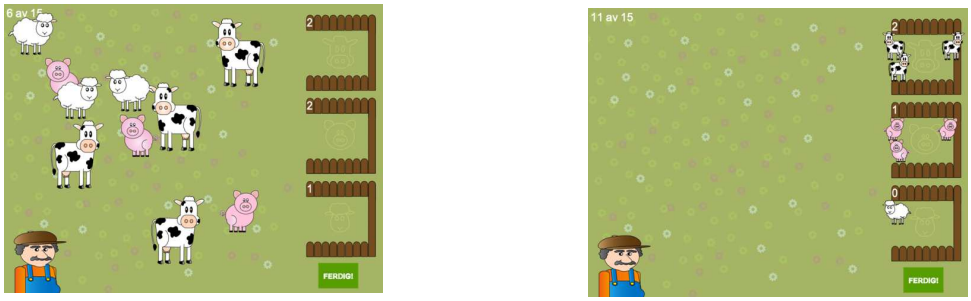

Figure 1. Various tasks (sorting, plus and minus)

The game was designed taking into consideration the affordance of the multitouch table. Children were able to point at and move the animals using gestures. The multitouch table offered different gestures such as drag and drop, rotate, scale, zoom, and Lasso clustering (grouping objects with one finger). Since the target users for the game are six-to-seven-year-old children, we reduced the possible gestures to drag and drop. Children could drag the animals and drop them in their respective pens.

Figure 2. Farmer Alfred’s facial expressions

3. User Tests

Two user tests were conducted to evaluate the multitouch tabletop game. In the first test, four adults with different backgrounds tested both the multitouch table and the PC versions of the game "Learning Math with Farmer Alfred" in mixed order. A questionnaire adapted from the GameFlow framework [21] was answered and individual interviews were conducted after the test. Based on the feedback from the first test, some improvements were made to the game. In the second test, three children played the tabletop version and pre-tests and post-tests were conducted. Observation and informational conversations with the children and their parents were the main methods of data collection.

3.1 Test 1

Four adults (A1–A4) participated in the first test. A1 had extensive knowledge about different technologies and was familiar with interaction design. A2 was a pre-service teacher. A3 worked in a kindergarten. A4 had neither technology nor education background or experience. The goal of Test 1 was to investigate the player experience of the game and gather feedback from different perspectives in order to improve the design.

After being introduced to the test, participants were asked to play the mutitouch table and PC versions of the game. They were encouraged to think aloud during the game play. After they finished both games, they were presented a questionnaire where they gave numerical rankings of various aspects of the two games. Interviews were conducted after the questionnaire. Questions in the interview focused on general feelings about the games, including experience, collaboration and learning aspects and which one they thought was more engaging for the target group.

The criteria in the questionnaire were adapted from the GameFlow Criteria for player enjoyment in games [21]. Our criteria included:

- **Concentration:** Game should require concentration and the player should be able to concentrate on the game.
- **Challenge:** Game should be sufficiently challenging and match the player's skill level.
- **Player skills:** Game must support player skill development and mastery.
- **Control:** Player should feel a sense of control over their action in the game.
- **Clear goals:** Game should provide the player with clear goals at appropriate times.
- **Feedback:** Players must receive appropriate feedback at appropriate times.
- **Social interaction:** Game should create and support opportunities for social interaction.
- **Learning:** Game should integrate learning and play, and should provide the expected learning outcome.

There were several statements in each criterion. The participants gave a score from 1 to 5 for each statement with 1 signifying that the participant strongly *disagreed* with the statement, and 5 signifying that the participant strongly *agreed* with the statement.
Table 1 shows the detailed scores given by each participant based on the criteria. In Table 2, MT represents the game "Learning Math with Farmer Alfred" played on a multitouch table. PC represents the same game played on a PC.

On average, "Learning Math with Farmer Alfred" received 4.15 points on a PC and 4.33 points on a multitouch table. Participants with technical backgrounds focused more on user interface and usability, which explains why they gave lower scores to the criteria regarding technical solutions. Participants without technical backgrounds gave higher scores. However, in "Learning," the multitouch table version received a lower score than the PC version.

Table 1. Scores given by the participants

	Concentration		Challenge		Players skills	
	PC	MT	PC	MT	PC	MT
A1	3.0	4.0	4.25	4.25	4.0	4.5
A2	4.6	4.6	4.0	4.0	4.0	4.0
A3	4.5	4.5	5.0	5.0	4.75	4.75
A4	4.0	4.0	4.25	4.25	4.5	4.5
Average	4.025	4.27	4.37	4.37	4.31	4.43
	Control		Clear goal		Feedback	
	PC	MT	PC	MT	PC	MT
A1	3.0	4.0	3.5	3.5	2.75	3.0
A2	3.0	5.0	5.0	5.0	4.5	4.5
A3	5.0	5.0	4.25	4.25	5.0	5.0
A4	5.0	4.0	4.75	4.75	4.75	4.75
Average	4.0	4.5	3.37	4.37	4.25	4.31
	Engagement		Social Interaction		Learning	
	PC	MT	PC	MT	PC	MT
A1	4.0	4.5	1.0	4.0	4.0	3.5
A2	5.0	5.0	2.0	4.0	4.5	4.5
A3	4.5	4.5	4.0	5.0	5.0	5.0
A4	4.0	4.0	2.0	4.0	5.0	5.0
Average	4.37	4.5	2.25	4.25	4.62	4.5

Participants were interviewed after they played the games. In general, they reported that the design was appealing to the targeted user group. Most of them thought that children would be immersed in the game. A4 herself was so engaged in the game that she did not hear several of the questions that we asked. The participants were also very positive towards the audio feedback and Farmer Alfred's changing facial expressions. A1 suggested that the players should be able to hear the instructions several times in case they forget them. A1, who gave a lower score in "Learning," commented that it was possible for children to focus more on the fun of playing the game on a multitouch table; therefore, they may not achieve the expected learning outcome.

After the first test, we made some improvements to the game. For example, in addition to giving the players instructions at the beginning of the game, we also gave them the chance to look at the instructions during the game. They only had to touch Alfred and the instructions would be given based on where they were in the game. We also made Alfred more visible in terms of his different facial expressions. In addition, we improved the interaction between Alfred and the players. Now, the transition between levels is no longer automatic. Instead, Alfred says, "Congratulations!" after each level is finished, and before players can move to the next level, Alfred asks, "Are you ready for the next task?" which makes the game more engaging.

3.2 Test 2

The second test was conducted after the improvement. Three children (C1–C3) participated in the test and played the game "Learning Math with Farmer Alfred" on a multitouch table. C1 was a 6-year-old girl. C2 was a 6-year-old boy. C3 was a 7-year-old girl. C1 and C2 played the game together, while C3 played it alone.

Before the game had started, we made tasks for pre-test and post-test together with a school teacher. The two tests were not the same, but had the same types of tasks. Each test included three sorting tasks, four addition tasks and four subtraction tasks. These tasks were represented by figures instead of numbers so that they were easily understandable for the children. Because C3 had higher level math skills than the others, we removed the sorting tasks and replaced the figures with numbers in the tests. During the game, questions were asked to the children to understand what they were thinking. We also recorded the time the participants spent on the pre-tests and post-tests.

The game was found to be intuitive and the children appeared to know what they were supposed to do by looking at the table; however, the table was too tall and wide for the age group, and they often had to stand on their toes to reach an animal on the other side of the table. Based on observation, we found that the children were very engaged and excited. One enthusiastically said, “This is fun!” several times during the game.

C1 and C2 played together but we found unbalanced activities between them. The one who was closest to the control buttons was found to be more active [18]. In the beginning, they did not communicate verbally what they had planned to do, so disagreement and collision ensued. Gradually, they developed a turn-taking routine after they were told that they should wait for their turn. C2 used the think-aloud method by himself and made comments to C1 when she made mistakes. They were very engaged and seemed to have immersed themselves in the roles and developed a relationship with Farmer Alfred. When Alfred asked, “Are you ready for the next task?” they would loudly answer, “Yes!” They looked very proud when Alfred praised them after each level and after all of the games were finished. Differing from C1 and C2, who mostly used a trial-and-error method, C3 took a more systematic approach, starting from the top pen and working his way down to the bottom pen. She also checked and made sure that the answers were correct before she touched the level’s “finish” button.

In the pretest, C1 made more errors in the subtraction tasks and C2 had only one wrong answer. Both C1 and C2 took about 5 minutes, while C3 took 3 minutes with no errors. In the post-test, both C1 and C2 had the same types of errors as in the pre-test, and C3 had no errors. However, all took 1 or 2 minutes less than they had in the pre-test. We also observed that the children went into a calculation “mood” after they had played the game.

4. Discussion and Future Work

In this paper, we present a mathematics learning game on a multitouch table. The results from the game flow evaluation show that the learning game on a multitouch table generally provides a better user experience than that on a traditional WIMP interface. Participants gave higher scores on most of the criteria for the multitouch game than that they did for the WIMP version. One can argue that since multitouch technology is new, it is more exciting than traditional WIMP technology. However, we can also argue that this is because interaction with a multitouch table is more natural and intuitive than interaction with a WIMP interface. Another reason could be that a large surface on the table allows for more social interaction than a standard PC monitor with a mouse and keyboard. For example, the table allows users to stand or sit around a horizontal tabletop. Based on this evaluation, we have reason to believe that multitouch technology can have a positive impact on children's learning experience and engagement.

The results of pre-and post-tests gave no clear indications of whether the children had learned better by playing the tabletop game. One reason could be that they only played the game for a very short period of time and that there was insufficient time between the two

tests. If participants had the opportunity to play the game for an hour every day for a week, and then be given a post-test, it is possible that the results would be clearer. Time shortages and the small number of participants made the analysis non-conclusive. Nevertheless, it showed that multitouch technology itself is rewarding in that it is an exciting and intuitive learning technology. When children are engaged, it is likely that they will learn better.

The children who participated in the evaluation were all enthusiastic and engaged in the tabletop game. All of them thought it was fun to play and they would like the opportunity to use such a table in their classrooms. These findings confirmed the results from earlier research which found that tabletop applications are enjoyable to use [4] and promote playfulness [12]. Today's generation is a game generation, which indicates that tabletop games may be a good complement to traditional classroom teaching.

Currently, we are conducting a more detailed data analysis focusing on interactive activities of children. We are also planning to move the table from the university lab to a school classroom for a longitudinal study.

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