DOES IT WORK?
USING COMPUTER GAME AS A TOOL FOR LEARNING – TEACHING EARLY ALGEBRA

Izabela Solarz

Pedagogical University of Cracow (Poland)

balt37@interia.pl

The question in this paper is if the suitably designed computer game may foster 12 years old children to enter the world of algebra. Particularly - the game concerns solving linear equations with one unknown (Dragon Box). What algebraic obstacles do students jump over using the game? How do they accustom to symbols? How can they transfer rules of the game to paper- and-pencil work? If we compare students who used game with others - do they make less mistakes? The results of using special digital tool by a group of students suggest that well-built computer game is obviously relevant didactic medium but cannot replace other tools. It seems to be a powerful supplement to other forms of teaching. For the process of learning the most important moment is the transfer from playing to paper-and- pencil-work that is why the part of a teacher is invaluable.

INTRODUCTION

What do we think about students at present? Are they really different than one day, some years ago? I think they are the same in a way. They need a goal and some kind of activity that would help them to reach it. They are different because they live in different world, they have different experiences; something else is interesting for them and something else is important. And this is the reason why our "old fashion" teaching doesn't fit to student's new possibilities.

Computer Games in Education

Digital games, an interactive technology within the multimedia learning environment, can effectively and interestingly foster learning processes, particularly among young learners. Well-designed educational video games offer meaningful learning experiences based on principles of situated learning, exploration, immediate feedback, and collaboration. The power of experiential learning in engaging contexts that have meaning for learners has been demonstrated in several studies (Shute, Ventura & Ke, 2015). Games are also thought to be effective tools for teaching complex ideas because they (a) use action instead of explanation, (b) create personal motivation and satisfaction, (c) accommodate various learning styles and skills, (d) reinforce mastery, and (e) provide interactive, decision - making context (McAlister & Charles, 2004; Squire, 2002). Moreover video games may create a new learning culture that better corresponds with the habits and interests of today's children and young adults (Prensky, 2001).

In math teaching, it is found that computer game utilizations foster the success level and creative ability of students in education and help to peer teaching and interaction that in turn creates a positive effect (Ozusaglam, 2007). Abrams (2008) mentions that computer games are strong motivation tools for math lessons. Analysis showed that using computer games in mathematics education improves students' self-efficacy for learning and improves their

interest in mathematical activities. In Keith Devlin's opinion modern devices allow us to greatly expand on the symbolic interface, which for many people is a known barrier to mathematics learning (Devlin, 2011). Though regulated by rules, computer games allow manipulation of objects, supporting development towards levels of proficiency (Fabricatore, 2000).They are said to be particularly effective when 'designed to address a specific problem or to teach a certain skill' (Griffiths, 2002), for example in encouraging learning in curriculum areas such as maths.

Potential benefits of using games during educational process are persuasive. But there is one more thing that I'm interested in - games are mainly used to facilitate tasks appropriate to learners' level of maturity in the skill, but players must possess such skills to some degree earlier. For me the most interesting would be the game that teaches completely new mathematics concepts and my research concern such a game.

Hypothesis

I designed special kind of learning. A group of 12 years old children were playing DragonBoxAlgebra5+ (http://dragonboxapp.com/) before they got to know anything about solving equations. Students have already looked for solutions of $x+ b = c$ or $ax = c$, but only by guessing or finding inverse operation. Starting the game they didn't know what it was about and that it was somehow connected with mathematics.

My hypothesis was: there is relationship between using the game for learning and reasonably manipulation of algebraic symbols in solving equations.

Rules of the Game

The game (DragonBoxAlgebra5+) starts from presentation of the table, divided into two parts and different cards. There is one particular card between them – a blinking box. The main principle says: "In order to win you must isolate the box on one side". Students follow the rules that say what move is needed to get rid of the useless cards: what to do if the cards are scattered, if they are stuck together, or if one is below another. One of the first rules says: "You can add the card from the deck". From now on the student always gets this information with a leaping picture on the deck of the board. He cannot make the next move until he places the same card on the other side.

Figure 1: The game

Next principles come in slowly and they are used in several examples before anything new is introduced. Having solved an equation the student gets feedback. It covers three points and gives three stars as an award: the first one - for leaving the box alone, the second one - for the

right number of moves, and the third one - for the right number of cards used. You can always move back. You can also solve your task again from the beginning. There is no timing in the game. Students have as much time as they need to finish.

The game starts from replacing colour icons but slowly the pictures are replaced by cards with numbers and letters. Soon "blinking box" is transformed to the card with "x". On one of the last levels the signs of arithmetic rules appear and the line dividing the board is replaced by the equal sign. The change from various cards to letters and initiation of using mathematics signs are barely noticeable. It's only new kind of pictures on which students already made moves according to well-known rules. However, manipulation on symbols starts to look like solving equations.

Learning Arrangement, Discovering

I carried out the plan of special learning arrangement in the group of 12 years old children. There were 20 students in the class. At first pupils were playing at school, using the interactive white board, but very soon most of them bought the game and got it on their own tablets or smart phones. During the first three lessons they had opportunity to play, discuss every example and look for the best strategy. They often moved back the steps, solving the task from the beginning several times. Some students cooperated, others worked without any help. Everybody wanted to take part in it and were really involved in the game. I acted rather like an observer – sometimes I helped students to understand English commands. I didn't interrupt, didn't make suggestions.
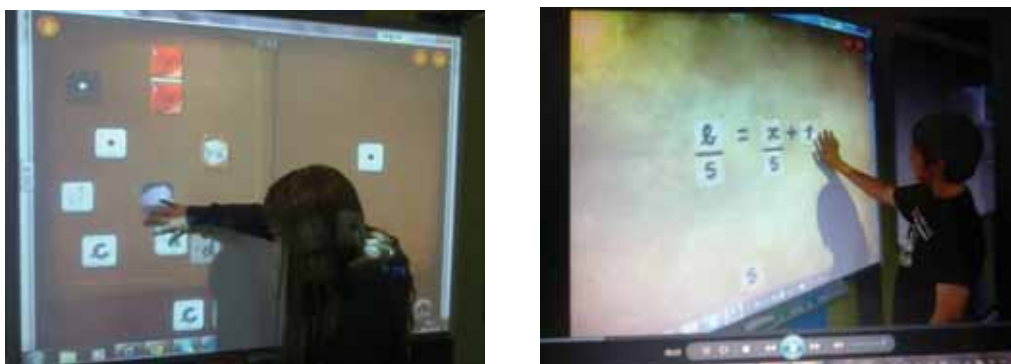

Figure 2: Students playing the game

I listened to my students and watched what they discovered. How did they join the pictures with numbers and the moves with arithmetic rules? How did they notice that bright and dark icons were like opposite numbers and what meant their disappearing after being moved one upon the other? If the same pictures were situated one below another you could get rid of them by dragging one to its twin. It looked for children like reducing a fraction. Some cards were stuck. It was sufficient to put one of such a card below that pair to make a fraction. Then you could use a preceding rule and divide the numbers. Students were not surprised when the pictures started to gather in groups joined with the sign of addition and in the place of line dividing the board the sign of equation appeared. Before this change there wasn't anything meaningful that the right side is equal the left one. Students only linked it with necessity of adding everything to both sides of the board. This rule is stressed all the time – you can do nothing if the move isn't repeated.

In more difficult examples students thought about the order of the moves. What was more effective – to start from putting a card below another one? - then you had to do the same to all groups of cards; or maybe it's better to get rid of useless cards from the side where the "x" card was blinking? Sometimes they took away the pictures from the side without the box, but then opposite cards appeared on the other side. They noticed that it's very important to see where the box is at the beginning to decide about the order of moves.

Students made a lot of mistakes and moved back many times. I can say – they learned by their mistakes. Sometimes they solved the problems together or they worked in pairs so there was opportunity to dispute a lot. I didn't chip in. After getting the feedback about the stars they knew what was wrong – if it was correct, if the order was the best and if there were no useless cards. Students didn't want me to help – they preferred to look for their mistakes by themselves.

The game gave children much pleasure. They enjoyed mathematics lessons. They also played after the lessons, during the breaks. They discussed, compared their achievements.

Learning Arrangement, Paper-and-Pencil Work

After such amusing introduction by playing, I said that it was time for transferring the same to paper-and-pencil work. We started from the easiest equations. I encouraged students to transfer the rules of the game to code all needed operations in such a way, that it would be legible and understood. Students created notation for: adding cards from the deck, moving one on the other, dragging cards. Ideas were very rich. We chose the best solutions.

The first problem was how to write down the addition of cards to both sides. There was no possibility to drag a picture with a finger. Students added the numbers writing them on border sides of the equation. They drew the arrows to code the addition and they wrote the results below them. Putting number below another one they added the fraction line. Or they stuck on the number to the number to get rid of a fraction. Sometimes it was clear in the writing that a student only placed numbers next to each other – like in the game — and after a while he put the multiplication sign. Every new operation they wrote down using different colour to mark it off. They used game language - "I drag on top, I place below..."

First examples were very simple. They consisted of one operation only. Students have already solved such equations, but only by guessing or finding inverse operation. I encouraged them to compare what they did before with the rules of Dragon Box. I often asked a question: Which way is easier for you in definite task – doing operations on both sides or rather finding an inverse operation? Students decided what to do differently in different situations. I think they often tend to forget methods that they learned earlier – trying to do everything in one way, without a reflection that it's possible to do it differently.

During such a transfer from the game to paper-and-pencil work it's very important to pay attention to the meaning of the expression "solution of the equation" and to verify its correctness. Students don't get the feedback yet. The only way to check the solution is to substitute and calculate.

The next problem was how to remember about repeating every operation on both sides. The game reminds about it from the first to the last level. The added card is leaping on the deck as long as the move is repeated on the other side to every group of cards. Now there is no reminder. Children agreed that using colour pencils helps them to remember about both sides. They often checked their solutions and compared them. I posted up incorrect answers and they were looking for the mistakes. Very soon students expected some kinds of errors so they

were looking for special ones. Some students started to abandon writing single operation but more often it led to the wrong solution. Taking the notes of every transition gave them more chances that they would succeed.
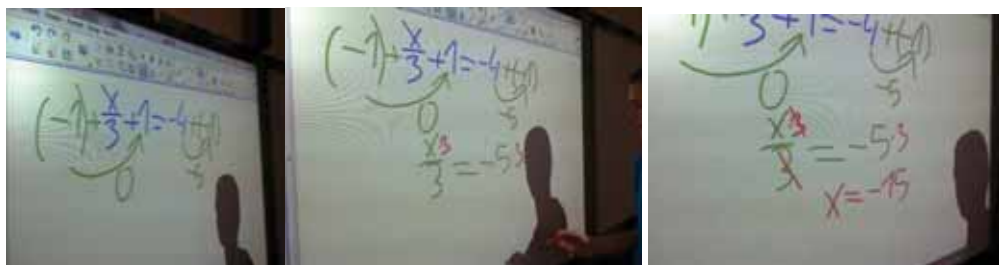

Figure 3: Students and their calculations

Very slowly students started to use the specific algebraic language in the place of language of the game. But they always could adduce to Dragon Box. Particularly in more difficult, doubtful situations – coming back to the game helped them to take the proper decision.

Learning arrangement, New types of equations

The first part of DragonBox5+ is just an introduction to solving linear equations with one unknown. There are only equations with an unknown on one side of the equality sign. But it can give opportunity to make a new research, encourage students to transfer the rules to new equations, for example: **2x +5 = x + 6** . 12 years old students have already known how to add expressions like **2x + 3x**. In the game they got used to see (-x) like a dark version of x, so it was nothing new to add (-x) if it was necessary. The game also makes children familiar to leave x on any side – it doesn't matter which one .The aim was the same: to isolate x. Children asked their own questions too, for example: which side would be better? Very soon they decided that it was more safe to add (-x) to both sides than to add (-2x) because of positive result on the left side.

It appeared that the new type of equation wasn't so hard, students just applied earlier experiences and it was like creating the next levels of the game.

The Results of Comparison

A year later I tested a group of pupils from the point of view of solving linear equations with one unknown. It was a group of 100 students from five different classes, taught by three different teachers. There were 20 pupils among them that had played DragonBoxAlgebra5+ and then continued with DragonBoxAlgebra12+. The others were taught in the traditional way – using the balance metaphor.

Group E – (experimental group - students using the game)

Group T – (traditional group - students who didn't play the game)

	Some kinds of mistakes	Group E	Group T
1	Students forget about operations on both sides	8%	19%
2	Mistakes like: 4x – x = 4	0%	5%

3	Incomprehension of the algebraic structure	0%	6%
4	Students didn't start on a task	2%	7%
5	Troubles with the sign of equation	0%	4%
6	Creating "quasi methods"	2%	5%

Table 1: Results of comparison

Students had to solve a few equations - with the unknown on one side only, or with unknown on both sides. There were also different coefficients – integer and fractional. Some of the equations needed only single operation to do and in others students had to transform the expressions.

Testing the students had two main goals – the first one was to answer the question: "What kind of mistakes did students make?" The second one was to compare students using the game with others. Did they make less mistakes? Which mistakes were less frequent?

There are some general conclusions: the experimental students less frequently forgot about both sides of equation. They didn't mistake unknown with numbers. The misconception of the algebraic structure was also less frequent. Group T didn't start on the task more often and had more troubles with the use of the equation sign. They also created their own - wrong - "quasi-methods" more often.

How Could Playing the Game Influence the Results?

In my opinion playing such a game can foster children to solve equations because:

From the beginning students get used to distinguish between "blinking box" and the other cards, so then they don't mistake the unknown with numbers.

It's impossible to make any move if you don't repeat the operation on both sides of the board – the main rule in balance metaphor is also the main one in the game.

Children solve the same problem many times, looking for the best solutions, so they get to know algebraic structure of expressions, considering the order of moves.

The box can be situated on each side – it doesn't matter which one.

They discover the rules and create the notation by themselves so they remember it all better.

Students are not afraid of symbols and operations, they use them, try them. They are not afraid of the failure so they want to start on every task.

When students solve equations, they can call the rules of the game in every moment to remember which move was necessary in such a situation.

Conclusions, Plans for Future Research

Well-built computer game used as a tool for discovering of mathematics is obviously a relevant didactic medium. It encourages learning. It is also very close to students' interests; most of them spend many hours playing different games. I think it's worth taking advantage of this situation. Firstly – the game shows something new, secondly - the game provides incentive for the player to keep practice. Solving equations seems to be boring and sometimes never-ending for many pupils but as we know - it is essential to be able to use algebra in the future.

I also agree with Keith Devlin who said that games cannot be the only way that students should learn math. They can be a powerful supplement to other forms of teaching, because they are ideally suited for learning basic math. But they cannot replace good textbook, cannot replace the teacher first of all (Devlin, 2011). There are other good sources of mediums that I use to teach algebra – for example: special kinds of blocks or well prepared computer applications. If children have more different models to learn it's easier for them to cross the following algebraic thresholds.

The results of testing showed me some problems with the understanding of the concepts "solution" or "set of solutions". Sometimes students have no idea how to finish solving the equation 2x = 5x or 0 = 3x or 2x = 2x + 1. They have problems with answering the question: what numbers are the solutions? And their answers suggest a lot of misconception. I am looking for the reason of such troubles. I think it's a good idea to use special blocks for it. I mean Lab Gear - special manipulative designed to model algebra concepts (http://www.mathedpage.org/manipulatives/alhs/alhs-0.pdf). In the future I'm also going to investigate its use for solving more equations with two variables, for example, and for inequalities.

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