We are living in an age when games on ICT-devices (smartphones, tablets, computers) are easily accessible for many children. Designers of many of these games consider that they teach children mathematics. One of these is DragonBox whose designer claims that children will learn the basics of algebra in an hour. Since algebra is considered by many to be a difficult part of mathematics it seemed valued to investigate whether DragonBox did involve children in algebraic thinking. Although there is research done on the mathematics in games on tablets, little is known about children’s engagement in mathematics from playing commercial games, such as DragonBox. In this exploratory study, one child’s interaction with DragonBox is examined to determine the mathematical powers, such as specializing and generalization, which John Mason suggested young children possess and which are important in algebraic thinking. The child was filmed during three 30 min sessions. It was found that the child often used more than one power at the time such as conjecturing and imagining or generalizing and classifying. The child did use all powers, although some were used more frequently than others.

**INTRODUCTION**

In this day and age, young children have access to ICT apps and games from an early age. Many of these apps and games are marketed to parents and preschools as involving young children in learning mathematics. However, not much research has been done to determine what kind of mathematics learning young children gain from interacting with them. The designers of the game DragonBox claims that children can learn algebra through their game (“we want to know”, n. d.). As well, Mason (2008) suggests that children have mathematical powers to produce algebraic thinking and that difficulties with algebra in schools is due to the lack of opportunities to make use of these powers, rather than the actual availability of the powers. Therefore, I was intrigued to look more closely at a child’s interaction with the game DragonBox and posed the question: Does one six year-old child use Mason’s mathematical powers, while playing the game DragonBox?

**YOUNG CHILDREN AND ALGEBRA**

Many mathematics education researchers have suggested that young children can be introduced to algebraic concepts (Radford, 2007, 2012, Mulligan & Mitchelmore 2009, Highfield & Mulligan, 2007). Although Radford (2007) highlights that algebraic thinking is about thinking in certain distinctive ways and not about using letters, almost all of the studies conducted with young children have focused on developing understandings of patterns. For example, Carraher and Schliemann (2007) conducted three longitudinal studies in the USA with 113 students, age 7-10 with the aim of documenting how the students’ algebraic thinking developed when
algebraic principles were introduced. Their results suggest that the children developed their algebraic thinking through working with patterns. Radford (2012) states “early algebraic thinking is based on the student’s possibility to grasp patterns in culturally evolved co-variation ways and use them to deal with questions of remote and unspecific terms” (pp 130). Mulligan and Mitchelmore (2009) also stress the importance of awareness of pattern and structure in the mathematical development of young students. In Highfield and Mulligan’s (2007) study, preschool children worked with patterns, using interactive technological tools.

According to Blanton and Kaput (2005), algebraic thinking can be regarded as “a process in which students generalise mathematical ideas from a set of particular instances, establish those generalisations through the discourse of argumentation, and express them in increasingly formal and age-appropriate ways” (p. 413). In research about algebraic thinking in the early years it seems like the age-appropriate way is dealing with patterns (Carraher & Schliemann, 2007, Radford, 2007, 2012, Mulligan & Mitchelmore 2009, Highfield & Mulligan, 2007).

Dougherty and Slovin (2004) did a research and development project, Measure Up, where mathematics was introduced through measurement and algebra in grades 1-3. Stating that if children are to understand generalized statements and be able to classify problems into larger groups to create efficient solving methods, Dougherty & Slovin (2004) suggest that mathematics should be introduced through measurement and algebra. Their findings strongly suggest that young children are capable of using generalized diagrams and algebraic symbols to solve problems (Dougherty & Slovin, 2004).

One of the basic components of working with patterns is the ability to notice differences (Radford, 2007). Mason (2008) considers that the ability to discern differences is just one of the different mathematical powers, which children already have long before they start school. He describes these powers as: Imagining and expressing, focusing and de-focusing, specializing and generalizing, conjecturing and convincing, classifying and characterizing (Mason, 2008). However, to think mathematically these powers need to be developed and brought to the surface, so that children use them intentionally, “the issue is not whether these powers are available, but that people sometimes fail to make use of them” (Mason, 2008, p. 67).

The powers that Mason (2008) describes have similarities with Bishop’s (1988) six mathematical activities; counting, locating, measuring, designing, playing and explaining (as explained in Nordahl, 2011). Children can use both Bishop’s activities (1988) and Mason’s (2008) powers without reflecting on their relationship to learning mathematics. In the studies about early algebra already mentioned (Radford 2007, 2012; Carraher & Schliemann, 2007; Mulligan & Michelmore 2009), the focus has been on the children’s development of algebra, but little research has been done on children’s own explanations for their algebraic thinking/actions. Studies such as Highfield and Mulligan (2007) used pre and post tests to determine the learning
against criteria set up the researchers which could explain why children’s perceptions have not been included.

Palmér and Ebbelind (2013) conducted a study that explored how the design of iPad applications affects the mathematics that is possible to learn and the dialogues between children and teachers in a Swedish preschool. Their findings suggest that the non-interactive applications seemed to hinder free dialogues and the consequent directed dialogues were then focused on the correctness of children’s answers.

The mathematical goals in the Swedish preschool curriculum are based implicitly on Bishop’s (1988) six activities (Utbildningsdepartment, 2010), whilst the curriculum as a whole stresses the importance of playing and learning through play (Skolverket, 2010). Therefore, in Swedish preschools, in order for ICT-supported learning to be appropriate, it must be conducted through play (Lange & Meaney 2013). Lange and Meaney (2013) investigated what mathematics could be seen in 33 different applications for iPads, which were considered to be based on playing. All of the applications except for four were recommended by blogging parents (Lange & Meaney, 2013). As well Highfield and Mulligan (2007) state that ICT can support young children’s mathematical learning, including about early algebraic concepts, if the software is playful and thus enjoyable for children. Lange and Meaney (2013) state that even though applications can provide favourable circumstances for learning mathematics playfully, the communication between the playing child and an adult enhance those possibilities.

THEORETICAL BACKGROUND

In the book *Algebra for the early grades*, John Mason (2008) writes a chapter about children’s powers to produce algebraic thinking. Mason (2008) suggests that children already have great powers for making sense of the world at large, when they start school.

They know what food to expect at different meals, they know about getting dressed, and they know about different rules of behaving in different situations. (Mason, 2008, p. 57)

Furthermore Mason (2008) claims that when the powers are developed and used in the context of number and relationships, algebraic thinking is taking place. The powers that Mason (2008) suggests children possess are:

- Imagining and Expressing: Imagining involves all or any of the senses and can help to get access to details that do not come immediately to mind. An example of expressing is when children describe their imaginations, for example in words, sound and movement (or in other ways), or describes perceived generalities or connections.
- Focusing and De-Focusing: To detect relationships between objects, or features of objects and to focus ones attention on some detail and then to shift
from one detail to another, but also to defocus to be able to take in a larger whole.

Specializing and Generalizing: To see through the particular to the general and intentionally look for examples and counterexamples shows the ability to generalize and specialize.

Conjecturing and Convincing: To try out conjectures, testing and see how to modify them when necessary. Try contentions to convince others that one’s conjecture is correct.

Classifying and Characterizing: Sorting and organizing a collection of objects. To stress some relevant feature and ignoring others requires one to be able to discriminate those features.

In this research, one child’s interactions with a tablet app, Dragonbox, is explored in relationship to these powers.

DRAGONBOX

The game Dragonbox was created by the company “We want to know”. It is available on multiple platforms, such as computers and handheld devices. There are two different versions: 5+, for children 5 years and over, and 12+ for children 12 years and over.

On the Dragonbox-homepage, there are several pdf-files with information on where the math is “hidden” in the game. However, this only describes the mathematics in the 12+ version of the game and nothing is specified for the 5+ version except a table that shows the difference between the different versions, such as how many levels and the availability in different languages. Having played both version, I can see that there is a great similarity between the 5+ version and the first levels of the 12+ version. Consequently, I assume that these first levels of the 12+ version are equal to the 5+ version. The developer (“We want to know”, n. d.) states in the pdf “Where is the math in Dragonbox” that in the first levels, the player will learn several mathematical rules.

![Figure 1: Get the box alone on one side to win; Level 1 - Sublevel 1](image)
In the first level, the players are introduced to the game. The instructions make it clear that there are two fields on the screen, defined by two rectangles. To “win” – or advance to the next level – you have to get a box alone on one of the sides. (see figure 1)

The player is introduced to the different tiles and told that each tile has a “dark side”, which represents “negative numbers”. When one “fair” tile is paired together with a tile with the same motif, but with the “dark side” facing up – a “green vortex” appears, which represents zero (see figure 2 and table1). “We want to know” (n. d.) claims that this teaches the player Additive Inverse Property ($a + (-a) = 0$) and Additive Identity Property ($a + 0 = a$).

When playing, a new “action” is introduced with an interval of four to eight sublevels. The actions include adding extra tiles or multiplying the factors. Each action teaches the player an algebraic rule according to the developers (“We want to know”, n. d.). There is in total 5 levels, each level containing 20 sublevels. For each level there is a dragon that evolve a little with every completed sublevel.

In figure 3 the player is introduced to a fraction bar
and the Multiplicative Inverse Property \((a \cdot (1/a) = 1)\). The Multiplicative Identity Property is present just four sublevels after that, as shown in figure 4. During the rest of level 2 and level 3, no new properties are presented, but the already-presented properties are combined in different forms.

In the first sublevel in level 4, the player is presented the first number sentence (equation) and the first equality sign, although it is made up by tiles instead of numbers or variables (see figure 5). During level four the sublevels evolve from picture tiles to dice tiles and in the last sublevel letters there are variables and numbers.

In the last level – level five – the sides in the background have disappeared and all sublevels are using only letter and number tiles (see figure 6).

At the end of the 5+ version the player is challenged with fractions and mathematical equations as seen in figure 7.
<table>
<thead>
<tr>
<th>Tile</th>
<th>Fair/Positive side</th>
<th>Introduced in sublevel/level</th>
<th>Dark/Negative side</th>
<th>Introduced in sublevel/level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box</td>
<td></td>
<td>From the beginning</td>
<td></td>
<td>Level 2 Sublevel 3</td>
</tr>
<tr>
<td>Green vortex</td>
<td></td>
<td>From the beginning</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Picture (example)</td>
<td></td>
<td>Level 1 Sublevel 2</td>
<td></td>
<td>Level 1 Sublevel 3</td>
</tr>
<tr>
<td>Dice (example)</td>
<td></td>
<td>Level 1 Sublevel 3</td>
<td></td>
<td>Level 1 Sublevel 3</td>
</tr>
<tr>
<td>Letters (example)</td>
<td></td>
<td>Level 1 Sublevel 12</td>
<td></td>
<td>Level 1 Sublevel 12</td>
</tr>
<tr>
<td>X as the unknown</td>
<td></td>
<td>Level 1 Sublevel 18</td>
<td></td>
<td>Level 5 Sublevel 16</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>Level 2 Sublevel 20</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Numbers</td>
<td></td>
<td>Level 3 Sublevel 14</td>
<td></td>
<td>Level 3 Sublevel 15</td>
</tr>
</tbody>
</table>

**Table 1: Tiles of DragonBox**

Table 1 summarises which tiles are introduced according to the levels and sublevels of the game.

**METHOD**

The data for this paper are videos of a six-year-old Swedish boy, Julian, playing DragonBox on a tablet. Julian is my nephew and we spend time together on a regular basis, therefore Julian was very comfortable as the research participant. Although he was very familiar with tablets, he had not played DragonBox before. The videos are of three 30 minute sessions. During these sessions, Julian played and I sat beside him. During the first session a tripod was used for the video camera, but since it was hard to see the screen when Julian played, in the following sessions I held the camera. He was a bit nervous of the camera for the first five minutes, but it wore off as he became more engaged in the game.
During the sessions there were discussions between us, which could be initiated by either of us. The discussions were not planned in any detail, but I had planned to prompt Julian to give explanations about what he was doing. Consequently, I had anticipated asking questions, such as “What are…?” “Why are you/they...?” and “What happens if…?”

Each of the videos was watched with the intent to identify when Julian used which power (Mason, 2008). It was not always easy to separate the powers being used in a specific interaction. Sometimes only one power was evident but mostly more than one power seemed to be used at the same time.

PLAYING THE GAME

While playing the game Julian realized that a dark sided tile with the same motif as a fair tile equalled a “green vortex”. He discovered that it did not matter if the tile was a fish or a tile with a “dice”-motif (see Table 1). This implied that he used the power of Focusing and De-Focusing.

Julian: (Talking about the fair and dark side of the tiles) It doesn’t matter if it is a fish or a one, if they are the same [motif in one fair version and one dark version] it’s a green vortex [if you put them together]

Julian also saw through the specific (the sort of motif) to the general (the dark and fair side of the tile, no matter what the motif – as long as they were the same) showing the power of Specializing and Generalizing. Another example of specializing and generalizing is the comment Julian made about the “green vortex”.

Julian: (When playing a level with number tiles instead of animal and/or “dice” tiles) Now the vortex is a zero! (from there on calling all vortexes zeroes)

Julian stressed the feature of the zero and generalized that the green vortexes could also be considered as zeros, as he had discovered that their features were the same.

He continued to use these powers, while discovering the different features of the game:

Julian: (Talking about tiles on the side that does not have a box) It’s not worth it to do anything here, [pointing to that side] since it will make it fill up [on the other side].

Here Julian ignored the urge to act on all tiles, since acting on the wrong tiles would make the task (to get one box alone on one side) harder to reach, proving that he had the power to defocus, discerning details and recognizing relations.

When it comes to Imagining and Expressing, Julian expresses his imagination around the dragons several times.
Julian: (About the test tube with a dragon which evolves at one level) Think when I finish many levels it’ll [the dragon] just BOOM as it grows and grows

Julian is imagining what will happen when the dragon evolves and gets bigger. He imagines the blast/explosion he thinks will appear when the dragon does not fit in the test tube anymore. Julian uses his imagination to predict what might happen. As when he says:

Julian: (Pointing at a “picture tile”) If I put that [an identical picture tile] there [directly under], then it’ll be a one [tile with the symbol for one on a dice], but it’ll be harder to get the box. [Tries it out] Yes. It turns to one but now there are loads here [pointing at the side where there is a box, that to win, should be isolated]

The above comment is also an example of Conjecturing and Convincing. Julian has an idea – a conjecture - of what is going to happen, and tries it out. He was not sure if he was right, therefore it was not knowledge. He had to try.

The power of Classifying and Characterizing is strongly connected to the powers of Specializing and Generalizing and Focusing and De-Focusing. All three powers are concerned with the ability to detect relationships between objects or features of objects, to stress the relevant feature and ignoring the others.

Julian: (Talking about tiles with letters instead of picture or dice motif) It’s just the same as the dices and the pictures, they only want to trick you that it’s harder. You just do the same things.

In this example, Julian classified the tiles as being dice tiles, picture tiles and now letter tiles, while at the same time he is generalizing the features of the tiles and the rules of the game. He is also characterizing the important features and de-focusing on the details and focusing on the general features.

**DISCUSSION**

This study shows that children can engage with tasks requiring algebraic thinking which are not to do with patterns. While playing the game of DragonBox, Julian used all the mathematical powers described by Mason (2008). The powers most frequently used were the powers of Focusing and De-Focusing and Specializing and Generalizing. The only power that sometimes was isolated, in that it was not connected to the other powers, was the power of Imagining and Expressing, when Julian talked about the dragons evolving. Since this was an exploratory study with just one research participant it is not possible to say that all six-year-olds would show their powers playing DragonBox, still it cannot be assumed that they do not. However the powers may go unnoticed if the child is to play the game without adult interaction. As Lange and Meaney (2013) suggest, interaction with an adult increases the potential for mathematical learning.
This paper does not study whether or not Julian actually understands the algebraic rules, or have just learnt the rules of the game. Rather it shows that DragonBox does activate his powers. Further research is needed to investigate whether other children also activate their powers in a similar way to Julian when playing the game but also how transferable his understandings from playing the game are to other situations requiring similar algebraic thinking.

REFERENCES


We want to know (n. d.) Where is the math DragonBox algebra 12+ Retrieved from http://wewanttoknow.com/resources/DragonBox/Math_In_DragonBox.pdf