IPADS AND MATHEMATICAL PLAY: A NEW KIND OF SANDPIT FOR YOUNG CHILDREN?

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In Swedish preschools, it is the responsibility of teachers to provide learning opportunities through children's play. Although anecdotal evidence suggests that ICT is becoming more common in preschools and that young children actively engage with ICT in play situations at home, there is little research on how ICT can contribute to playful mathematics activities. Data from a study of young children using iPads in home situations indicates that Bishop's six categories of mathematical activities can be seen in free, downloadable apps. It was also clear that features of some apps supported the children being more playful than other features.

Keywords: ICT, play, Bernstein, home situations, Bishop's mathematical activities

ICT, MATHEMATICS AND YOUNG CHILDREN

Although there is no list of requirements about what children should do, the Swedish curriculum is clear that preschools and teachers have a responsibility to provide learning opportunities based on play, including mathematical ones (Skolverket, 2010). Therefore, if information communication technology (ICT) is to be used to support learning then it must be through play and this means finding out from children what playful learning with ICT could be. To do this, we take the advice that Prensky (2006) gave to parents about not buying "educational" computer games for their children–"a far better strategy in my view, is to take the games your kids already play, and look inside them for what is educational" (p. 184). Consequently in this research, we identify the mathematics in the apps that one child played and begin an investigation into why they were engaging.

However, almost all previous research, which has looked at how ICT supported mathematical learning, has been from the perspective of investigating what young children learnt from engaging with specifically-designed educational software in preschool settings (see for example Highfield & Mulligan, 2007). After reviewing the literature on children using ICT, Sarama and Clements (2009) suggested that the affordances of computers made them more advantageous for developing mathematical thinking than physical objects because, "compared with their physical counterparts, computer representations may be more manageable, flexible, extensible, and 'clean' (i.e., free of potentially distracting features)" (p. 147).

An emphasis on school mathematics in these specially designed programs is problematic in situations where learning is supposed to occur through play. This is because play has certain features, as summarised by Docket and Perry (2010):

> The process of play is characterised by a non-literal 'what if' approach to thinking, where multiple end points or outcomes are possible. In other words, play generates situations

> where there is no one ‘right’ answer. … Essential characteristics of play then, include the exercise of choice, non-literal approaches, multiple possible outcomes and acknowledgement of the competence of players. These characteristics apply to the processes of play, regardless of the content. (Dockett & Perry, 2010, p. 175)

The use of play as the basis for learning activities affects the roles available to the teacher and children. From examining an activity where preschool children explored glass jars, we found that although the teacher could offer suggestions about activities, the children did not have to adopt them and could suggest alternatives (Lange, Meaney, Riesbeck, & Wernberg, 2012).

However, from related research (Johansson, Lange, Meaney, Riesbeck, & Wernberg, 2012), it was clear that mathematical variety was not lacking in these play situations. We found that all of Bishop’s (1988) six mathematical activities, which underlie the Swedish preschool mathematics curriculum (Utbildningsdepartementet, 2010), were present in play situations that children engaged over several days. Bishop’s activities have a different background and focus than the topics often connected with school mathematics, although there is some overlap. The activities were:

> Counting. The use of a systematic way to compare and order discrete phenomena. It may involve tallying, or using objects or string to record, or special number words or names.
>
> Locating. Exploring one’s spatial environment and conceptualising and symbolising that environment, with models, diagrams, drawings, words or other means.
>
> Measuring. Quantifying qualities for the purposes of comparison and ordering, using objects or tokens as measuring devices with associated units or ‘measure-words’.
>
> Designing. Creating a shape or design for an object or for any part of one’s spatial environment. It may involve making the object, as a ‘mental template’, or symbolising it in some conventionalised way.
>
> Playing. Devising, and engaging in, games and pastimes, with more or less formalised rules that all players must abide by.
>
> Explaining. Finding ways to account for the existence of phenomena, be they religious, animistic or scientific. (Bishop, 1988)

Of the 12 situations illustrating the 6 activities that we considered in Johansson et al. (2012), 3 came from a sand pit. It was clear from what the children were doing– filling buckets, making pretend gardens, driving toy cars–that they were involved in play because, for example, the children exercised considerable choice, adopted non-literal approaches, produced multiple outcomes and were acknowledged as competent in their actions. Our thinking about how a sandpit facilitated children’s play and supported their engagement with mathematical ideas made us want to explore whether ICT, iPads in particular, could provide similar mathematical learning opportunities. Anecdotal information suggests that many young children play with ICT at home and we considered that information from home situations could be informative for preschools. Our research questions for the study are:

1) What mathematics can be seen in apps for the iPads that young children play?
2) What features of these apps support children's play?

METHODOLOGY

Data was collected from children, aged between four and six, engaging with apps on iPads. In this paper, we use video data of a six-year-old boy, Miguel, who currently lives in England. Although he had played computer games at home, he had not used an iPad before and so was not familiar with the apps. Over four days, he played games for 1-1½ hours each day. The data discussed in this paper is from the last session. By this time, Miguel was familiar with the apps and made choices of what to play based on his interests. Being videoed was also no longer a novelty. Although he had already spent time in an English primary school, he would not have started school until the month when the data was collected if he had been living in Sweden.

Miguel was recruited as a co-researcher to evaluate the suitability of the apps for a four-year old child. We explained that he was better at making these judgements as we were too old. One of the authors, Tamsin who was his aunt, videoed Miguel's activities with a small video camera. At times, there was discussion between them, sometimes initiated by Miguel and at other times by Tamsin. The discussions were not planned but occurred as a natural part of Miguel's engagement with the apps.

Before meeting with Miguel, 33 different apps, which were recommended by one of three sources, were loaded onto the iPad. The apps were all free, although some operated only for a short period before payment was needed to move to a higher level. Fifteen apps were recommendations from *Pappas appar* (Pappa Daniel, 2011), a blog where a Swedish father had placed links to free apps for iPhones and iPads for young children, based on his own children's interests. Four apps came from Apple's store (Apple, 2012), under the category of being education and mathematics. The remaining apps came from a US mother's blog (PragmaticMom, 2012). On this site were recommendations from the mother as well as from other people. Once the apps were downloaded, Tamsin played them all. Some apps were about basic number facts. However, in most apps the mathematical ideas were more invisible.

Initially the data were analysed to identify which of Bishop's six activities occurred in the apps that Miguel played. This information was recorded in a table. During this analysis, notes were made about the features of the app that seemed to support Miguel's engagement with it. Once the analysis of the mathematical categories was completed, the notes about the features were considered and general themes/points identified. One of the themes, which was connected to Miguel's willingness to use an app, appeared to relate to how visible the mathematics was.

We could distinguish 3 levels of visibility of the mathematical ideas. To clarify how this visibility was related to the definition of play we used Basil Bernstein's (1971) ideas about the degree of classification and/or framing of content. In our context, framing is about whether it is the app or the player who has control:

> over the selection, organization and pacing of the knowledge transmitted and received in the pedagogical relationship. … Strong frames reduce the power of the pupil over what, when and how he receives knowledge and increases the teacher's power in the pedagogical relationship. However, strong *classification* reduces the power of the *teacher* over what he transmits as he may not over-step the boundary between contents, *and* strong classification reduces the power of the teacher *vis-á-vis* the boundary maintainers. (Bernstein, 1971, pp. 51-52 italics in the original).

In our case, the app and by implication its designer, replaces the teacher in the pedagogical relationship. Wang, Berson, Jaruszewicz, Hartle and Rosen (2010) discussed the importance of "the virtual world product developers who incorporate decision making options that the users can manipulate" (p. 36). As exercise of choice was one of the key features of play (Dockett & Perry, 2010), consideration of who controlled what content was used and how it was used were of interest. Although Tamsin took part in discussions with Miguel, she made no suggestions about "the selection, organization and pacing" (Bernstein, 1971, p. 51) of what he did. The exception was after Miguel had spent considerable time having a dog in the *Talking Tom 2* app make farting noises, Tamsin suggested that he found another app to play.

In Miguel's engagement with the apps, it was possible for us, as researchers, to identify the mathematical content, such as ideas about numbers, but it often would have been invisible to others, especially young children. At the most visible level, a player could not engage with the app without being aware that they were using mathematics as was the case with *Factor Ninja*, described in the next section. In this case, the mathematics could be considered as strongly classified and well insulated from other content (Bernstein, 1971).

At the next level, the mathematics was semi-visible, lying somewhere in between a strong and weak classification. Often apps had several parts and one or more of them required Miguel to use mathematical concepts. However, the focus of the app was not on the mathematics. Instead the mathematics was used to achieve another purpose. In *Tavern Quest*, the player earned money when a meal was sold. This could be used to quicken up meal production or to buy necessary skills for a quest. In this case, rather than the content being strongly classified because it was integrated with other content, there was strong framing because there was no choice in the selection of the content that had to be used.

At the third level, the mathematics was completely invisible. For example, in *Toca Hair Salon - Christmas gift*, measurement ideas about the length of the Christmas Tree's hair were part of considerations of how the hair should be styled. In these cases, the designer has not insulated the mathematics from other contents and the content selection depended upon the purpose of the app. Classification and framing were weak (Bernstein, 1971). Emilson and Folkesson's (2006) research in a Swedish preschool, suggested "a weak classification and framing can promote the possibility for children to participate on their own terms" (p. 235). Therefore, classification and framing in an app is likely to affect whether it is considered as play by the children.

IPADS AND BISHOP'S 6 MATHEMATICS ACTIVITIES

Over the hour, Miguel played eleven different apps, sometimes for a very short time, such as *Tavern Quest*, and others for much longer periods, such as *Meeblings* and *Toca Hair Salon – Christmas Gift*. Only in *Talking Tom 2* was it not possible to see any of Bishop's six mathematics activities.

Counting

Factor Ninja had mathematics as its sole content and required composite numbers to be sliced into their prime factors. Therefore, the contents of this app were strongly classified (Bernstein, 1971). Miguel did not know what prime or composite numbers were but was aware that there was no choice in the selection of knowledge he needed to use. This was the only app where he went to the explanation to find out what he had to do. However, the explanation required too much reading for a six year old. He also "died" too quickly to learn them from using the app. Consequently, he did not engage for long. Nevertheless, he explicitly named the numbers he was slicing.

Knattematte appeared to be very similar to a school-like number activity. In one part of the app, a simple addition was given in numerals and then with apples and a choice of four numerals appeared on the screen. The correct numeral had to be tapped, but when Miguel tapped a wrong numeral, it just shook. As well, he found he could eat the apples by tapping on them. Although the mathematics in the app appeared to be strongly classified and framed, the way Miguel engaged with it suggested that he was able to blur the boundaries between contents and determine what content should be used.

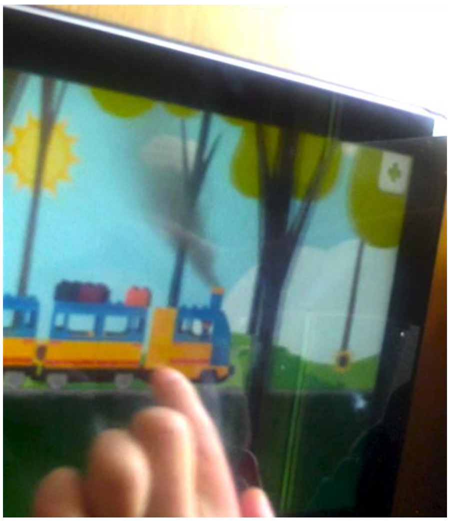

Figure 1: Duplo Jams–train activity

In other apps such as *Duplo Jams*, the counting was less visible. In one activity a train ran along a track. Duplo bricks fell from the sky and if the train moved slowly, they landed on it (see Figure 1). After a discussion about the relationship between the train's speed and catching the bricks, Miguel said "I've just got, now I've got 3". Then another brick landed on the train and Tamsin said "There you go, how many now?" As two more bricks fell, one after the other, Miguel stated "I've still got lots." Tamsin said, "How many's lots?". After some distractions, Miguel counted them and said "Eight, eight". Knowing how many bricks were on the train was not essential for the game, but the way the bricks fell, one at a time, facilitated a systematic noting of how many there were. Thus in this app, counting could be considered both weakly classified–there were no distinct boundaries between it and other content, such as the train's speed–and weakly framed as Miguel could control what content was his focus.

Locating

Locating is about exploring one's spatial environment. In some apps, location skills were needed and this supported them being discussed. In one part of *Bamba Ice*, Miguel had to tap a numeral between 1 and 9 on a cash register to indicate the price he should pay for an ice cream he had designed. A purse then opened to reveal an equal number of coins to the price chosen, although this match was not clear from how the coins were shown in the purse. Miguel had to drag the coins one at a time to the cash register drawer to pay for his ice cream. Sometimes his dragging meant the coin was just outside the drawer, so it was returned to the purse and he had to start again. Although in this last session, we did not discuss why it took him a long time to get all the coins from the purse to the drawer, in a previous game, Tamsin had mentioned how important it was to make the coin go wholly into the drawer. The choice of what Miguel had to do in order to move to the next stage was controlled by the app, making it strongly framed. However, the lack of visibility about what content he was expected to use–location skills–suggested the activity was weakly classified.

Measuring

Measurement knowledge was needed only for some parts of the different apps, affecting the degree of visibility. In the app *Order Up*, Miguel was expected to judge when different items were "cooked" by reading a scale. However, as was the case with several apps, the mathematical content was not always Miguel's focus.

Miguel: Cook eggs, cooking eggs this time, I've never cooked eggs before.

Tamsin: No, it looks like you've got to cook both sides as well. Do you remember how to flip them?"

When the meter moved to perfect for one side, he flipped the egg

Tamsin: Yep, flip it, that's it.

Then he moved to another part of the app and the "cooking" was not completed and the cooking of the egg was labelled "poor". Then as Miguel refocused on the "cooking", Tamsin intervened so the scale reading became part of the discussion.

Tamsin: Argh, you didn't wait till it was all done.

Miguel: Of what?

Tamsin: Hang on, wait till that one gets up there (pointing to where the meter has to get to for it to be perfect). Remember, it's got to be put in here (pointing out the dinner plate which must be pressed in order to save the meal).

He tapped on the dinner plate when the meter reached “perfect” on the second side.

Tamsin: That’s it go, go!

Miguel: Perfect!

In home situations, the boundaries between school and everyday knowledge, such as between measurement and cooking, are likely to be blurred, suggesting that classification is weak. However, in a virtual environment of an iPad app, the blurring was perhaps not so clear to Miguel. Although he had seen eggs being cooked, it was unlikely he had cooked any himself. With Tamsin’s intervention, the need to read the scale was reinforced making the measurement knowledge strongly classified. Miguel had little choice about what to do, suggesting that framing was also strong.

Designing

Designing was a large part of several apps that Miguel played over the four days. The one that he repeatedly returned to was *Toca Hair Salon*. In this app, Father Christmas or a Christmas Tree could get a new hair style, by using various equipment and accessories. In the final session, Miguel placed Christmas decorations of the tree and coloured its needles different colours. He turned his finger into a hair dryer by clicking on an icon and rearranged the needles (see Figure 2).

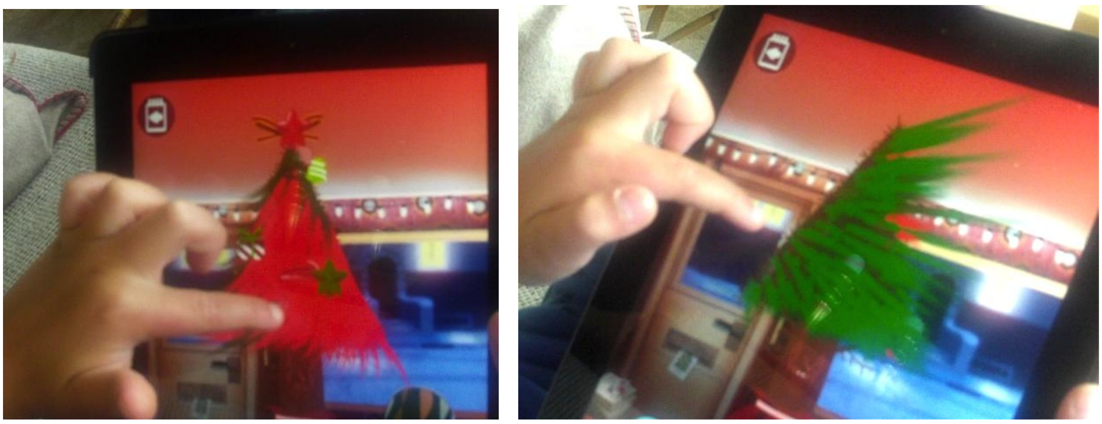

Figure 2: Christmas Tree gets a new hair style

Both characters in this app changed facial expressions as Miguel gave them different styles. The tree’s face showed surprise when the hair was cut and then became sad when the needles were made so long that they cover its face. Miguel said “Why is he feeling so sad? I’m putting his hair back.” Tamsin answered “Maybe because it’s a little too long for him?” Miguel said “Because he doesn’t like it on his head.” Tamsin replied “Yeah, it’s in his face. I don’t like having hair in my face either.” Although the tree’s face seemed to register happiness, sadness and surprise, it was not always clear what the connection was to Miguel’s actions. Nevertheless, the feedback that Miguel gained from the characters encouraged his continued engagement.

The designing knowledge that Miguel used was not isolated from other contents about hair, hair styling and Christmas trees, suggesting that classification was weak.

Framing also appeared weak because Miguel had significant control over what he chose to do and the order in which he chose to do it.

Playing

Apps designed for young children require them to conform to certain rules but these rules were usually embedded. Given that children have limited if any reading skills, apps need to be operated intuitively. For example, in the *Meeblings* app, different coloured Meeblings had to be tapped in a specific order to rescue other Meeblings. After several unsuccessful attempts at a level, Miguel checked the solution, by tapping on this word and watching what he had to do. This suggests that what is considered to be the content of rules is neither weakly or strongly classified. However, the constraints they placed on players' choices about what they could do indicated they were strongly framed. In the train game in the *Duplo Jams* app, Miguel had to know from other experiences, that raising railway barriers might move the train forward. When he first came to them, Tamsin had to tell him what to do. In a later attempt, Miguel did it himself and said "It's easy, see. It's easy, easy this time."

Explaining

When Miguel first engaged with the apps, he rarely talked about what he was doing even when questioned. His attention seemed focused on determining what he had to do. Only after he was familiar with the apps did he seem able to discuss them. However, when he became comfortable with the app, it still had to be challenging for him for him to continue to play it. Therefore, opportunities for discussions, including explaining what was happening, only arose on a few occasions. Of Bishop's (1988) six activities, this was the one which was the least represented.

The embeddedness of the rules also meant that models of explanations were rarely provided, although sometimes, Tamsin provided them. In *Play Lab* a shape was traced over and then appeared, as a solid shape on the screen. In one game, the shapes were combined to form a car which drove along a road. Miguel's tracing was not always recognised by the app and twice when he tried to trace a circle, a square appeared. His car ended up with two squares on its roof.

Miguel: What is that?

Tamsin: I think it's a car, isn't it? … A car with parcels on the top.

Miguel found that by tapping on the car, which was now driving, he could make the squares wobble and eventually fall off.

Miguel: See, I'm trying to put the parcels down. See I put them down.

Miguel's explanation of how he made the squares jump off the car involved focusing Tamsin's attention on his actions. Miguel's explanations were weakly classified because what they was not clearly insulated from other content, such as making statements about what was occurring. As well, framing was weak because the control of what was and what was not transmitted was largely up to Miguel who used his everyday knowledge to form the explanations.

CLASSIFICATION, FRAMING AND SANDPIT PLAY

Almost all of the apps that Miguel chose to use on the final day of his “research” using the iPad contained one or more of Bishop’s mathematical activities, although opportunities to provide explanations were limited. Nevertheless, as Prensky (2006) suggested, the apps that Miguel engaged in did contain educational material.

At the same time, it was clear that six-year olds, who are at the end of preschool in Sweden, may not recognise that they were doing mathematics while engaging with the apps. This was because the focus was on something else. In apps, such as *Knattematte,* which most adults would consider to be about number knowledge and thus strongly classified, Miguel found other aspects of the app to focus on. When the mathematics was invisible, there was a blurring of boundaries between mathematical and other contents as Miguel responded to the different challenges in the apps, making is weakly classified. A similar case could be made for the mathematics that children engage with when playing in a sandpit.

On the other hand, the apps that seemed to be most play-like in the ways that Miguel engaged with them were those that were weakly framed. In these cases, Miguel choose what he did and how and this facilitated him to try out different approaches and explore different outcomes, such as was the case with *Toca Hair Salon*.

It cannot be assumed that because a researcher considers an app to use mathematical concepts that children can build on the concepts or make connections to other concepts. However, it cannot be assumed that children do not do this either and so longitudinal research is needed in this area. Regardless of whether an app was considered to be weakly classified, framed or both, describing what he was doing, especially when he used explanations, seemed to provide Miguel with opportunities for his mathematical thinking to become more visible. It also seemed to allow him to be challenged in other ways than those required by the apps. Thus, apps have the potential to provide opportunities for playful mathematical learning but interaction with an adult would contribute a significant amount to realising this potential.

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