ROBOT TECHNOLOGY AND NUMBERS IN THE CLASSROOM

Gunver Majgaard
The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, gum@mmmi.sdu.dk

Morten Misfeldt
Danish School of Education, Aarhus University, mmi@dpu.dk

Jacob Nielsen
Center for Playware, Technical University of Denmark, jn@playware.dtu.dk

ABSTRACT

This paper describes an initial exploration of how a cubic user-configurable modular robotic system can be used to support learning about numbers and how they are pronounced. The development is done in collaboration with a class of 7-8 year old children and their mathematics teacher. The tool is called Number Blocks and it combines physical interaction, learning, and immediate feedback. Number Blocks supports the children's understanding of place value in the sense that it allows them to experiment with creating large numbers. Surprisingly, the children found it great fun to pronounce very large numbers, and also competed to find who could build the largest number. This created a close link between the stated learning goals, game play, and the Number Block tool.

KEYWORDS

Learning, modular robot technology, technology in education, physical serious games, experimental design, mathematics.

1. INTRODUCTION

This paper describes an initial exploration of how a tailored implementation of the generic user-configurable modular robotic system named I-BLOCKS (Nielsen, 2008a) can be used to support number learning in mathematics. More specifically, the educational goal is to support children's understanding of place value by allowing them to physically play with multi-digit numbers, the pronunciation of which is quite complicated in Danish (Ejersbo 2009). The target group is children aged 5-8. Development was carried out in an experimental design process actively involving a class of normal schoolchildren and their mathematics teacher. This experiment is cross-disciplinary, combining the two scientific areas of robotics and pedagogical research. The tool used is a specifically targeted implementation of I-BLOCKS named Number Blocks. It combines physical interaction, learning, and immediate feedback.

This educational tool can be labelled as a physical serious game (Majgaard 2009a). Number Blocks is inspired by prior examples in the field of physical serious games by e.g. Papert (1980), Resnick (Rusk 2008) and Majgaard (2009b).

The question explored in this paper is: Can Number Blocks support the understanding of place value in 5-8-year-old children? An experimental design process inquires into how robotic cubes and physical interaction support children's understanding of place value. The scientific method used is design-based research focusing on developing new software technology (van den Akker, 2007).

This paper contains an introduction to numeracy and interaction. This is followed by a description of the technological platform and an introduction to the way numbers are pronounced in Danish. Then comes a description of the iterative development process. Finally there is a discussion of the results and research question.

2. THEORY

Comparative investigations have shown linguistically-determined differences in the conception of numbers and in understanding of place value (Dowker et al. 2008, Miura et al. 1989). One of the reasons for these differences lies in the extent to which the words used to denote numbers reflects in a regular way the base ten place value system (Dowker et al. 2008).

Danish words for the numbers between one and 100 do not reflect the base ten place value system in two ways: (1) the words for the teens (11,12,13 ...) and the decades (20,30,40 ...) does not in any significant way relate to the names of the digits 1-10, and (2) the decades and units are spoken in reversed order compared to how they are written as digits in the base ten system. As an example of these two problems you would say 'fem-og-tres (five-and-threes)' in order to express the number 65, 'tres' (60) is an inflection of 'tre' (3), showing how the Danish number-words relate to long gone base 12 and 20 systems (Ejersbo 2009). The reversed order of digits between 20 and 100 also affects larger numbers such as 27,000 (in Danish 'syv og tyve tusinde' that is 'seven and twenty thousands'). The algorithm to create larger numbers in Danish is described in figure 1.

It is broadly acknowledged that learning of mathematics can be considered an embodied activity (Johnson 1987, Nemirovsky et al. 2004). Furthermore concept formation in mathematics relates intimately to the representations that are used when working with the specific concept (Duval 2006, Steinbring 2006). The Number Blocks tool provides an embodied interaction with two representations that are crucial in the formation of a number concept: namely the number written as digit and the words used for a number. Number Blocks can be viewed as a Montessori-inspired digital manipulative because it highlights interaction with abstract concepts (Zuckerman et al. 2005). Montessori-inspired digital manipulatives are contrasted with Fröbel-inspired digital manipulatives in the sense that the latter highlights creativity and agency (ibid).

3. TECHNOLOGICAL PLATFORM AND THE NUMBER BLOCKS TOOL

I-BLOCKS is a user-configurable modular robotic platform developed and tested through several prototype and application generations (Nielsen 2008b, Nielsen 2008c). It consists of cubic modules that connect to each other using magnets and can communicate with each other when so connected. Each cube can communicate with up to four of its six possible neighbours and is fully self-contained with respect to power, connectors and processing. At the edges of the four communicating sides of a cube are four RGB LEDs, which can light up in 4096 different colours. The I-BLOCKS communicate locally via infrared light, and in some cases radio (Zigbee), allowing interaction with a computer. Each I-BLOCK makes use of a 3D accelerometer to detect its orientation with respect to gravity. This makes it able to detect which side is facing upwards.

The I-BLOCKS hardware is encapsulated by a black polyurethane shell that has a soft rubber-like feel, with plastic fittings in top and bottom into which various sockets, connectors, sensors and actuators are integrated.

The I-BLOCKS have been developed specifically to provide a general platform for exploring physical programming. An I-BLOCKS construction results not only in a physical structure, but also in a particular computational functionality which is dependent upon that particular structure.

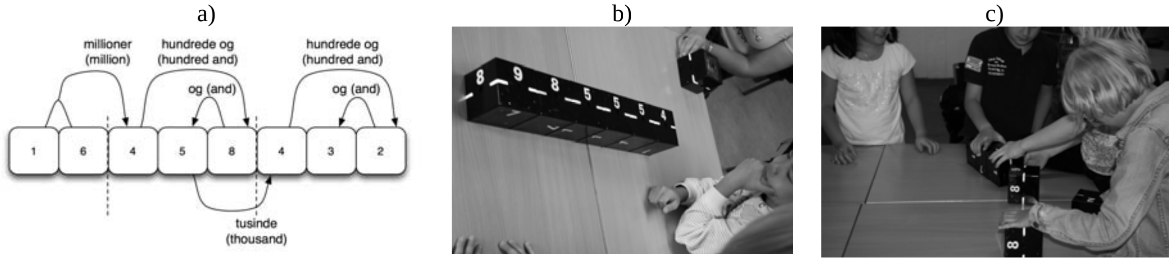
The Number Blocks implementation and instantiation of the I-BLOCKS technology allows children to explore the concept of number and the place value system in a tactile way, focusing on the way large numbers are constructed from digits and on the spoken names of these numbers. To create Number Blocks, each I-BLOCK module had a single digit attached to each face of the block. Note that six faces is not sufficient to represent ten digits, so individual modules could only represent a subset of digits. The digit labels were registered with the built-in accelerometer, so that when a module determines which face is currently facing upwards, it also knows which digits are facing in which directions.

The user connects Number Block modules in lines to create large numbers, which is equivalent to writing digits in lines to create larger written numbers.

The complete Number Blocks system consists of the above mentioned number modules, a Zigbee radio communication module and a PC with a Zigbee-USB dongle, which serves as an audio playback device converting incoming numbers into spoken numbers. The spoken numbers are consecutive playbacks of samples of recorded children's voices. A number algorithm plays the samples in the correct order. Figure 1gives the correct spoken order for 16,458,432: by following the arrows from the left we get 16 -> 'millioner' -> 400 -> 'og' -> 8 -> 'og'->50->'tusinde' etc.

Figure 1. a) The Danish system of pronouncing numbers. b) and c) Pictures from our final session. (b) The children enjoyed making large numbers. (c) The handy size of the blocks supported collaboration and playful investigation.

a) b) c)



4. THE DESIGN PROCESS

Our iterative design process included four sessions with our target group, each lasting approximately two hours. The themes for the sessions were: (1) Getting to know each other and the technology; (2) Brainstorming and decision making; (3) Recording sound; (4) Testing the prototype.

Session 1. Getting to know each other and the technology: The children tried an existing I-BLOCKS music application (Nielsen et al. 2008b). The goal of the session was to evaluate the potential of I-BLOCKS with the target group, and get to know each other, in order to make future cooperation easier for both children and researchers.

Session 2. Brainstorming and decision making: The goal of this session was to generate good ideas for creating a suitable educational tool on the I-BLOCKS platform. The children had ideas about how to use the blocks for mathematics, e.g. that one could add and subtract using the blocks. Besides brainstorming with the children we also had a session with a group of mathematics teachers from the same school. They suggested that one could use the blocks to help children by saying numbers. They told us that Montessori had some drills with bricks and positional notation. The research group had in an earlier brainstorm had a similar idea. We decided to design a system that supported place value and later to extend the system to include number operations.

Session 3. Recording sound and development of the first prototype: Our next step was to record the necessary numbers to make speech synthesis. To involve the children as co-creators in the design process, we chose to use the children's own voices.

Session 4. Testing the prototype: The goal of this session was to do usability testing and to assess whether there was enough potential in the design to go ahead. Our initial observations suggested that the children were interested in creating large numbers (Figure 1b), they were clearly interested in using Number Blocks to make as large a number as possible, either with all the cubes or with a specific selection.

Our initial concerns about the Danish number names were mainly centered around the first 100 numbers but the session showed that large numbers were very interesting for the children. This fact came as a surprise for the teacher since the class was only working with two digit numbers at that stage.

Another observation was that the children were able to play with Number Blocks. The session showed that the children (in groups of four) were able to create small games and competitions with the Blocks (See figure 1c), without being guided by the investigators. This was a surprise in the sense that this prototype version of Number Blocks was designed without intended gameplay. Furthermore the observations suggested that collaboration and competition was aided by the blocks fitting nicely into a child's hand.

Our observations suggest that the size of the blocks supported physical play including group interaction (see figure 1c).

5. SUMMARY

Small groups of 5-8 year olds constructed digit-blocks into larger numbers. The children were invited to say the number they created, then Number Blocks said it. Surprisingly, the children enjoyed expressing very large numbers such as 9,568,045. They also invented small competitions e.g. who could build the largest number. This tied the Number Block system very closely with the learning goals given.

6. CONCLUSIONS

This paper asks how I-BLOCKS technology can support 5-8 year olds in their understanding of the place value system. The "Number Blocks" instantiation of I-BLOCKS supported the children's understanding of place value very nicely. The time that the children spent playing with the Number Blocks, simultaneously made them better at expressing numbers.

The size of the individual blocks encouraged collaboration between small groups of children because the children were able to discuss and construct together.

The sessional nature of the design process allowed us to develop a good relationship the children and their teacher. That made it easier for us to focus on the learning goals and the learning process in the final session: testing the prototype of Number Blocks.

The next step of the Number Block project is to implement a comparison algorithm that allows children to compare the size of numbers. Such a tool should support playful exploration of relative number size.

REFERENCES

Dowker, A., Bala, S., Lloyd, D. 2008. Linguistic influences on Mathematical Development: How Important Is the Transparency of the Counting System? *In Philosophical Psychology*, Vol. 21, No. 4, August 2008, 523-538

Duval, R. 2006. A Cognitive Analysis of Problems of Comprehension in a Learning of Mathematics. *Educational Studies in Mathematics*, *61*.

Ejersbo, L. R. 2009. Hjerne og matematiklæring .*Kognition og Paedagogik* , 19 (72) .

Johnson, M. 1987. *The body in the mind: The bodily basis of meaning, imagination, and reason*. Chicago: University of Chicago Press.

Majgaard, G., 2009a. An outline of interaction types in physical serious games. *Proceedings of IADIS Game and Entertainment Technologies 2009.*Algarve, Portugal, pp.128-130

Majgaard, G., 2009b. The Playground in the Classroom - Fractions and Robot Technology. *Proceedings in Cognition and Exploratory Learning in Digital Age*. IADIS Press, 2009. Rome, Italy pp. 10-17.

Miura I. T., Okamota, Y. (1989): Comparisons of U.S. and Japanese first graders' cognitive representation of number and understanding of place value. *In Journal of Educational Psychology*, 81 pp. 109-113.

Nemirovsky, R., Borba, M., Dimattia, C., Arzarello, F., Robutti, O., Schnepp, M., Chazan, D., Scheffer, N. (2004) PME Special Issue: Bodily Activity and Imagination in Mathematics Learning. *Educational Studies in Mathematics*, 57 (3) pp. 303-321.

Nielsen, J., 2008a. *User Configurable Modular Robotics - Control and Use*. Ph.D. thesis, University of Southern Denmark.

Nielsen, J., Jessen, C. & Bærendsen, N.K., 2008b. RoboMusicKids – Music Education with Robotic Building Blocks. *The 2nd IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL)*, 149-156.

Nielsen, J. & Lund, H.H., 2008c. Modular robotics as a tool for education and entertainment. *Computers in Human Behavior*, 24, 234-248.

Papert, S., 1980. *Mindstorms. Children, Computers, and Powerful Ideas*. 2. Ed. Basic Books.

Rusk, N., Resnick, M., Berg, R., & Pezalla-Granlund, M., 2008. New Pathways into Robotics: Strategies for Broadening Participation. *In Journal of Science Education and Technology,* vol. 17, no. 1, pp. 59-69

Steinbring, H. (2006): What makes a sign a mathematical sign? – an epistemological perspective on mathematical interaction. *Educational Studies of Mathematics* 61, pp.133-162

van den Akker, J. et al., 2007. *Education Design Research.* Routledge.

Zuckerman, O., Arida, S., & Resnick, M. 2005. Extending Tangible Interfaces for Education: Digital Montessori-inspired Manipulatives. *CHI -CONFERENCE*, 859-868.