Designing Interactive Activities within Scratch 2.0 for Improving Abilities to Identify Numerical Sequences

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ABSTRACT
This paper presents the progress of an ongoing research aimed at developing the number sense in third graders. Based on assessment results of a sample of elementary schools in the Municipality of Zapopan, Jalisco, Mexico, we investigate the problem of mathematics learning with a cognitive approach. The study identifies the student's weakness related to their abilities to conceptualize the meaning of the numbers and its relationships. We present the main ideas of pedagogical design of a serious game developed in Scratch 2.0 that enhances the ability to identify and build sequences. Preliminary results suggest the use of a webcam to increase student's interaction and improve their numerical abilities.

Categories and Subject Descriptors
K [**Computing Milieux**]: K.3 Computers and Education; K.3.2 Computer and Information Science Education. H.5.2 [**Information Systems**]: User Interfaces – *User-centered design.*

General Terms
Design, Human Factors, Theory.

Keywords
Number sense, Scratch 2.0, design, serious game, interaction.

1. INTRODUCTION
Mathematics is defined as a science dealing with the logic of quantity and shape [11]. Since quantity is an abstract entity, its study implies previous training in several fields of knowledge, including Arithmetic. However, the accuracy, logical sense and abstraction are characteristics related to Arithmetic. Specific interrelated competences are needed for understanding arithmetic concepts. Researchers have identified these competences as number sense. The Number Sense (NS) is the ability to understand the meaning of numbers, relationship between them and the capability to handle real life situations that include numbers [2, 9, 12, 17]. NS includes abilities such as mental calculation, numerical estimation, and quantitative reasoning [6]. Furthermore, conceptual understanding of numbers also includes knowledge of place value, numerical relations, counting and sequencing, understanding and meaning of basic arithmetic operations [1]. Berch [2] suggests that NS can be considered as conceptual learning of mathematics. Researchers argue that number sense can be taught if is seen as knowledge [5, 9, 19]. We consider it would be feasible develop NS through a serious game.

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The present study investigates the importance of NS in third graders. Based on assessment results of a sample of elementary schools in the Municipality of Zapopan, Jalisco, Mexico, we design a serious game in Scratch 2.0 (http://beta.scratch.mit.edu/), for helping students to identify and build number sequences and develop SN. Our preliminary findings provide insight into how to improve the student's abilities to identify numerical sequences through interaction with Scratch applications [15, 16].

2. LEARNING DIFFICULTIES
In Mexico, learning difficulties in mathematics are accentuated at elementary school. Through the National Assessment of Academic Achievement in Schools (ENLACE 2012), the Secretary of Education of Mexico gets a reference of the knowledge and skills that students possess. In mathematics, third graders (ages 8-9 years), are evaluated in different abilities of NS (See Table 1).

Table 1. Structure of number sense test

Topic	Numerical task	Items
Meaning of numbers	Relative size	10
	Integer and rational numbers	4
Arithmetic operations	Addition-Subtraction	3
	Multiplication	3
Spatial location	Correspondence	3
	Multiplication-Division	3
Information analysis	Seek, identify and order	4

The results of ENLACE 2012 (http://www.enlace.sep.gob.mx), shows a national average efficiency of 44.3% in the subject of mathematics, where 55.7% of students are placed in levels considered as insufficient or elemental. This is an evidence of the student's difficulty for building mathematical concepts.

3. DATA COLLECTION AND ANALYSIS

To identify the components of greater difficulty of SN for third graders, we analyzed the results of ENLACE 2012 on a probabilistic sample of 107 primary schools in the municipality of Zapopan, Jalisco, where only 42.7% of the students are placed in domain levels considered good or excellent. The size is calculated from the variance of the population and the maximum acceptable standard error and a confidence level of 97%. The statistical treatment (See Table 2) shows that the results come from a normal distribution with 95% confidence (See Figure 1), which provides certainty to the analysis and allows subsequent generalizations.

Tabla 2. Tests for Normality for Wrong_Answers

Test	*Statistic*	*P-Value*
Shapiro-Wilk W	0.969048	0.0573082
Skewness Z-score	0.727409	0.466973
Kurtosis Z-score	-0.533503	0.593682

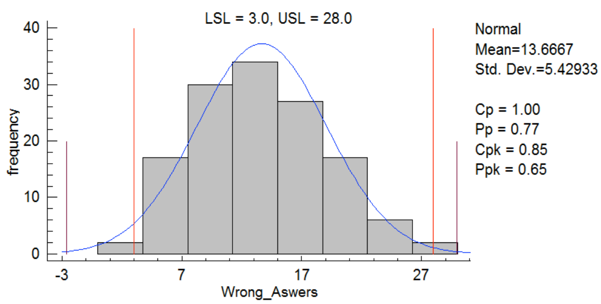

Figure 1. Process capability for Wrong_Answers

For data processing of learning assessment, we use tools provided by NodeXL 1.0.1, for their versatility with graphic analysis of networks, identification of nodes representing relationship between common attributes, analyze their connectedness and group them into clusters. Through the Harel-Koren Fast Multiscale algorithm, we identify clusters for elements of NS where students had greater difficulty (See Figure 2).

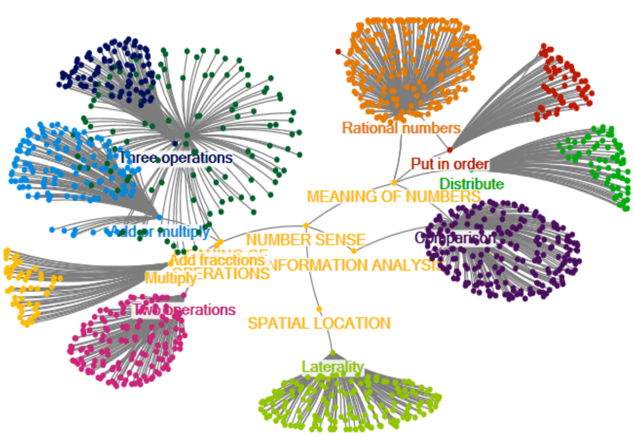

Figure 2. Clusters of number sense assessment

The clusters show that, for the students, the *meaning and use of the operations* is the most difficult ability of SN to build mathematical concepts (42%). However, the *meaning and use of numbers*, as prior ability, has 36% of the difficulty. It is desirable, therefore, to develop the ability to conceptualize rational and integers numbers, identify, compare and put in order. These concepts are addressed through the exercise of identification and construction of number sequences, which helps students to improve their understanding [13], and contributes to the development of NS to build arithmetic concepts [5, 9, 19].

4. PEDAGOGICAL DESIGN

Several researchers agree that a Serious Game (SG) is a computer game that aims to educate and train the user in a fun environment [1, 3, 8, 10]. SG provides a simulated environment with experiential learning activities [18]. Using games has a positive impact in the development of new knowledge. They encourage the acquisition of cognitive skills and improve the comprehension of students [4]. Play emphasizes the student's perception and attention, and allows him to overcome the limits of his sensory field [20]. To achieve the educative purpose, designing experiential learning activities is needed. The Instructional Design (ID), provides a pedagogical approach of SG and determines how to achieve the educational purpose, hence our intention to present the key pedagogical elements for a SG that promotes the development of skills *to identify and build number sequences*, in third graders.

4.1 Theoretical foundations

Vygotsky believed that knowledge occurs as a construction that derives from social interaction with the environment [20]. He establishes the Zone of Proximal Development (ZPD) as the distance between the student's ability for solving a problem independently (ZRD), and the level of potential development in which the student is able to solve the problem under adult guidance or in collaboration with more capable peers (ZPLD) [20]. Thus, development is seen as a gradual acquisition of knowledge through successive displacement between ZDR and ZPD. In this process, a developed skill allows students to solve tasks that are more complex, located in their ZPD. This does not mean completion of the learning, instead, represents a new ZDR.

4.2 Assessment

According to previous research, Hernandez [7] identified a Gradient of Knowledge (GK) with application in solving mathematical problems. The GK includes understanding, comprehension and assimilation, which can be seen as a series of ZDR and ZDP, according to the student's ability to solve a given problem [7]. The GK is the basis for ID with learning activities that give students the ability to scroll up or down through the phases of development, implemented as different levels in the SG, and allows continuous assessment of student's knowledge.

4.3 Instructional elements

To promote the development of SN, including development of *the ability to identify and build numerical sequences*, we designed a simple SG in Scratch 2.0, which is a visual programming environment designed by the Lifelong Kindergarten Group at MIT Media Lab [14]. The inclusion of two-dimensional graphic objects and its animation on stage constitute the environment in which projects are developed in Scratch. Programming is done by inserting command blocks forming scripts that control the object's animation [14]. These features, and the inclusion of video sensing and multimedia elements, allows users to learn in a playful environment, and makes possible the construction of mathematical concepts. For these reasons, and for its easy use in different systems, we choose Scratch 2.0. The proposed ID (shown in Table 3), includes issues of primary school curriculum.

Table 3. Instructional elements focused on identifying number sequences

	Instructional elements
Audience	• Student of third grade of elementary school (ages 8-9 years)
Entry behaviours	• Meaning of numbers • Addition - Subtraction • Number relationships
Instructional goals	• Identifying sets of quantities that vary proportionally or not, missing values and calculate proportionality constant factor in simple cases
Instructional objetives	• Identifying an element in a certain position • Identifying which of the numbers does not belong in a set • Establishing order • Predecessor and sucessor
Strategy	• Interaction with the SG through webcam for improving student's perception.

4.4 Interaction and design

The design of the game is supported by the previous pedagogical design, where student's interaction takes advantage of the features of Scratch 2.0, and helps develops cognitive student's abilities. Through the webcam, children perceived virtual objects of the game [15], furthermore, using the webcam, the software provides children with control of the virtual objects of the game by interacting with them.

Therefore, from the interactions design of the SG, cognitive conditions are established to allow students to acquire a kinesthetic perception, and together with visual and linguistic perception that provides the SG, stimulate the student's perception and attention directed towards the learning experience into game. The way in which the user manipulates the objects of the game and how adapts these animations to himself, constitute a cognitive process of use of tools, which is one of the key ideas of Vygostky [1, 20], and an advantage for designing in Scratch 2.0, because through the development zones it is possible to design different learning levels to achieve the educative purposes, in a SG.

5. STUDY LIMITATIONS

To study the development of the ability to identify and build number sequences through a SG designed in Scratch 2.0, we conducted a quasi-experiment. Since our research is in progress, we are reporting in this paper preliminary results and findings, which is useful to describe a phenomenon during an investigation [13].

Some aspects of this research method are the observation and monitoring a group of third grade students who interacted with the SG (Figure 4), for three 30-minute sessions spread over two weeks. This group, called exploratory, has 27 children aged 8-9 years. The comparison group consists of 22 children with the same age. Both groups belong to a local elementary school, and observe the same curriculum in the same time periods.

6. PRELIMARY RESULTS

A brief analysis of the institutional tests showed that students of the comparison group and experimental group, Figure 5, discovered the presence of three questions related with the ability to identify sequences. (a) On the issue of spatial location, *laterality* was evaluated as sub-item, from which students identify the position of a number with respect to another.

Figure 4. Screenshot of SG for identifying and build number sequences

Results did not show differences between both groups, since 100% of the students gave a correct answer; (b) on the issue of meaning and use of numbers, *to identify and to compare* were evaluated as sub-item. This ability allows students establish relations between numbers. The comparison group showed a 60% error, while the experimental group failure was 37%, which shows a change in favor of the experimental group; (c) The Sub-item to *order and build a sequence*, from which students are able to identify and build number sequences, there was a similar difference between both groups. The comparison group showed a 60% of error, and 40% of error en experimental group.

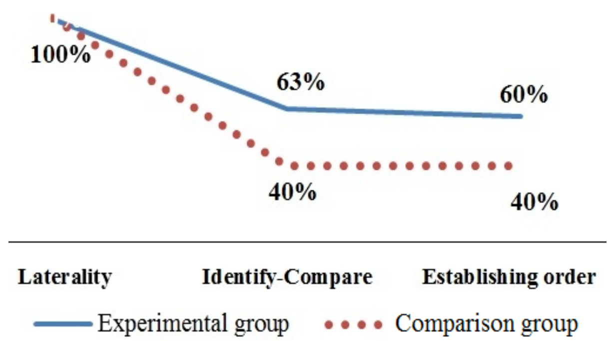

Figure 5. Prelimary outcomes for treatment with SG designed

We know about the limitations of this research, and how affect results. The short exposure time that is subjected the experimental group is the main limitation, and results could be questioned. However, it cannot be excluded that the slight variation in favor of experimental group, which can be a bit of learning, resulting from the interaction between experimental group and SG. This is something we will take into account on further development of the NS by using an interactivity game within Scratch 2.0

7. CONCLUSIONS AND FUTURE WORK

In this paper, we had briefly exposed the key highlights of SG designed to identify and construct numerical sequences within Scratch 2.0. From this we infer an alternative to improve mathematical skills of third graders.

It was observed that Scratch provides a user friendly environment, although it is missing several programming language features, which may restrict what can be implemented. However, the incorporation of a webcam enhances student's interaction and allows him to be part of the context of the game, explore and experiment. This features provides an experiential learning environment for learning's students in a fun environment

In this context, mathematical concepts are built, primarily by direct experience with the learning environment. Secondly, due to the student's interaction with the SG, and while he plays, his perception captures the stimuli that come from the digital environment, and through attention selects and organizes information. Since student acquires, retains and retrieves this information, he uses his memory and develops his thinking, which is manifested as ability to identify numerical sequences.

These findings represent a new benchmark for future research aimed at developing higher mental functions through the use of serious games, which is part of our future work, after concluding and replicating this research.

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