Development of Number Sense in Third Grade of Elementary School Using Serious Game

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Abstract: This research focuses on instrumentation of information technologies that become psychological tools, designed to develop number sense of third graders. The theoretical background is supported by the Cultural-Historical approach, and considers that, using a serious game; emphasize the student's attention and perception for constructing mathematical concepts. A preliminary outcome identifies numerical relationships and counting, as a field of opportunity to increase math skills associated with number sense.

Keywords: Number sense, serious game, artifact

Introduction

In early years at school is perceived the difficulty of students to build mathematical concepts and it is reflected in numeric skills. Different components of cognitive processes have been associated to a poor performance on that field. The aim of research is to identify new standards that foster cognitive processes of higher psychological functions of attention and perception, as a strategy to develop number sense in the third graders. To achieve this goal, we propose designing a serious game as psychological tool, that enables students relate the abstract operations of numerical entities with concrete objects, and navigate through different training paths, according student' cognitive level. It is hoped, from these mathematical learning experiences, that students develop their number sense.

1. Literature Review

1.1 Number Sense

The study of number sense is documented in several studies, which analyze the concepts and components of the skill needed to build mathematical concepts [1, 2, 3, 4, 5, 6]. Malofeeva et al. [3], establish that number sense is the ability to understand the meaning of numbers, relations between them and the ability to perform mental calculation, numerical estimation, and quantitative reasoning; furthermore, includes conceptual understanding of numbers, knowledge of place value, number relationships, counting and sequencing, understanding and meaning of addition, subtraction, multiplication and division.

1.2 Serious Games and Mathematics

Serious games (SGs), according Ling, Xiaoqiang and Dandan [7], are a category of video and computer games to train or educate users while giving them an enjoyable experience. SGs provides a simulated environment with experiential learning activities [8]. SGs can be

used as tools in schools to improve students' efficiency to learn [9], moreover, emphasize the student' attention and perception, to overcome the limits of their sensory field by doing a voluntary effort. The imaginary context of the game teaches the child to guide their conduct by the perception, situations that affect him, and the meaning of the situation. As result children learn to do, consciously, an activity, and acquire a development. Researches evidence the potential positive impacts of using games and serious games, with respect to learning, skills enhancement [10], therefore the advantages of use them in mathematics [11].

1.3 Artifacts as Psychological Tools

The Cultural-Historical approach of mediations, centered on the use of cultural artifacts, is widely used in mathematics learning [12, 13, 14, 15]. According to Vygotsky [12], the artifacts are cultural mediations, transformed as psychological tools, by the use of signs as language. The use of psychological tools promotes development of higher psychological processes as perception and attention, which are the source of a specifically human behavior [12, 16], necessaries to construct mathematical concepts [17]. The use of information technologies allow to exploit the potential of artifacts [14]. With SGs, the child could perceive its environment, and language help him to perceive objects immersed in it and the relationships between them. Through SGs and language, the child reorganizes its spatial and visual field, and creates a temporary field, which is real and perceptible for him. He captures changes and reconstructs the separate activities, therefore he develops his attention. These processes are necessary to construct mathematical concepts, and enables students relate the abstract operations of numerical entities with concrete objects [17].

2. Problem Statement

By the logical character and level of abstraction necessary to construct mathematical concepts, the students demonstrate cognitive difficulties, which are perceived by indicators of educative achievement [18, 19, 20]. In México, the problem is accentuated in third graders, whom must develop mathematical skills associated with number sense. However, statistics shows a score of 419 in math, when Organisation for Economic Co-operation and Development (OECD) countries has an average of 496 [20]; 52% of students are at levels considered unsatisfactory and show difficulty identifying numerical relationships, recognition of magnitudes and simple operations with numbers [19].

3. Contribution of the Proposed Research

Identifying new benchmarks in the transformation of higher psychological processes, for develop number sense, will be the major contribution of the proposed research. The incorporation of dynamic assessment and learning gradients, into a serious game, will be the second contribution. From these approaches it is expected to contribute to developing of skills of counting and numerical relationships as components of the number sense.

4. Proposed Research Methodology

4.1 Objective

To design a serious game that develops number sense, through transforming of psychological processes of perception and attention in mathematical contexts, looking to improve the skills of counting and numerical relationships in third graders.

4.2 Research Questions

The research will address these questions: How to enhance the development of the psychological processes of perception and attention by an instrumental approach? How a serious game develops number sense skills of third graders?

4.3 Hypothesis

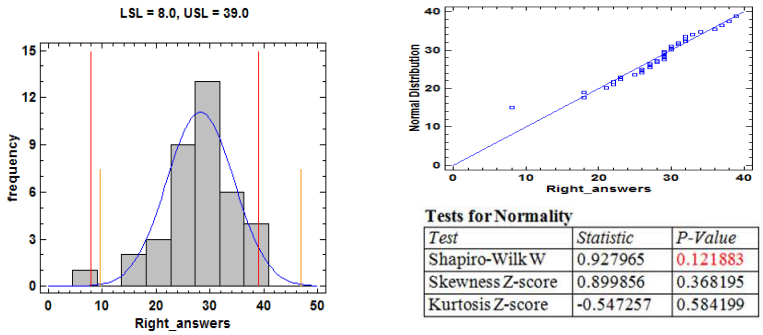
The use of serious game transforms perception and attention, and develops the skills of counting and numerical relationships of number sense, in third graders.

4.4 Research design

The research will adopt a combination of qualitative and quantitative methods to explore the development of number sense. At the first stage, the transformation of the psychological functions of perception and attention will be studied by the Genetic method of Vytgotksy [12], whose function is to study these processes in its functionality. At the second stage, two classes of third grade, will be randomly selected and assigned to the experimental and control groups. Students of both the experimental and control groups will sit for identical pre-test [21]. For six months, control group will use the SGs designed. After that, both the experimental and control groups will be subject to post-test, to measure development of the skills of counting and numerical relationships [21].

5. Preliminary Outcomes

A pilot study was conducted to identify mathematical abilities of third graders. During first part of the study, a test was designed on the basis of number sense concept, and the Mexican curriculum. After applying test, Coefficient alpha was measure (α=0.8) and the test's structure was reviewed to improve internal consistency. The figure 1 shows results of the study. In the second part of the study (See Figure 2), same test was applied to different students, and they expressed difficulty in properly resolving the items associated with numerical relationships (36%), counting (38%) and exercises for applying basic concepts of arithmetic operations (46%). These findings allow to identify areas of opportunity associated to number sense's elements. This can lead to design of strategies to exercising these specific skills, to develop number sense, looking for increase mathematics learning in third graders.



Tests for Normality

Test	*Statistic*	*P-Value*
Shapiro-Wilk W	0.927965	0.121883
Skewness Z-score	0.899856	0.368195
Kurtosis Z-score	-0.547257	0.584199

Figure 1. Analysis of internal consistency, of the number sense test.

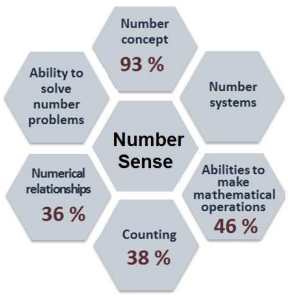


Figure 2. Results of the number sense assessment.

6. Conclusion and Future Work

Currently, we have been identifying areas of opportunity to improve mathematical skills, related with number sense. This allows designing strategies, for instance a serious game, to develop number sense. As future work of this study, the author is planning the following:

- Instructional design for SGs based on numerical relationships, counting and arithmetic operations, as categories of the number sense.
- Implementing a SGs with math problematizations, according student' cognitive level.
- Pre-test and post-test to measure skills of counting and numerical relationships.

From these processes it is expected to contribute to development of skills of counting and numerical relationships as components of the number sense of third graders.

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References

[1] Berch, D. B. (2005). Making sense of number sense: Implications for children with mathematical disabilities. *Journal of Learning Disabilities*. 333-339.

[2] Griffin, S. (2004). Building number sense with Number Worlds: A mathematics program for young children. *Early Childhood Research Quarterly*, 19, 173-180.

[3] Malofeeva, E., Day, J., Saco, X., Young L., & Ciancio, D. (2004). Construction and evaluation of a number sense test with head start children. *Journal of Educational Psychology*, 648-659.

[4] Jordan, N., Glutting, J. & Ramineni, C. (2009). The importance of number sense to mathematics achievement in first and third grades. *University of Delaware, United States*. Elsevier.

[5] Yang, D. C. & Wu, W. R. (2010). The Study of Number Sense: Realistic Activities Integrated into Third-Grade Math Classes in Taiwan. *The Journal of Educational Research*, 103:379–392.

[6] Tsao, Y. L. &. Lin, Y.C. (2012). Elementary School Teachers' Understanding Towards the Related Knowledge of Number Sense. *US-China Education Review B1*, 2012:17-30.

[7] Ling, H., Xiaoqiang, H. & Dandan, W. (2011). The Case Analysis of Serious Game in Community Vocational Education. *2011 International Conference on Computer Science and Network Technology*.

[8] Tang, S. & Hanneghan, M. (2011). "Fusing Games Technology and Pedagogy for Games-Based Learning through a Model Driven Approach". *2011 IEEE Colloquium on Humanities, Science and Engineering Research*, pp. 380-385.

[9] Janarthanan, V. (2012). "Serious Video Games: Games for Education and Health" *2012 Ninth International Conference on Information Technology*. IEEE Computer Society, pp. 875-878.

[10] Connolly, T., Boyle, A., MacArthur, E., Haney, T. & Boyle, J. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education 59*, pp. 661–686.

[11] Lorant-Royer, S., Muncha, C. Mesclé, H. & Lieury, A. (2010). Kawashima vs "Super Mario"! Should a game be serious in order to stimulate cognitive aptitudes? *Revue européenne de psychologie appliquée 60*, pp. 221–232.

[12] Vygotsky, L. (2008). *El desarrollo de los procesos psicológicos superiores*. Segunda edición. Barcelona.

[13] Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics*, 61: 103–131.

[14] Mariotti, M. (2009). Artifacts and signs after a Vygotskian perspective: the role of the teacher. *ZDM Mathematics Education 41*:427–440

[15] Puentedura, R. (2009). *Game and Learn: An Introduction to Educational Gaming*.

[16] Wertsch, J. (1995). Vygotsky y la formación social de la mente. España: Barcelona. Ed. Paidos.

[17] Tall, D. (1995). Cognitive Growth in Elementary and Advanced Mathematical Thinking. *Conference of the International Group for the Psychology of Learning Mathematics.* Vol I, pp. 161–175).

[18] ENLACE. (2011). Resultados Prueba Enlace 2011 Básica y Superior. SEP. Recuperado de http://www.enlace.sep.gob.mx/content/gr/docs/2011/ENLACE2011_versionFinalSEP.pdf

[19] INEE (2010). Panorama Educativo de México 2009. Indicadores del Sistema Educativo Nacional. Educación básica. Instituto Nacional para la Evaluación de la Educación.
[20] OECD (2010). *PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science (Volume I).* http://dx.doi.org/10.1787/9789264091450-en
[21] Creswell, J. W. (2011). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research* (4th Edition) Prentice Hall.