From Macroscopic to Microscopic Vision for the Acquisition of the Concept of Living Being by Primary School Children

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Abstract

This paper presents research that aims at using electronic sensors to improve sensory exploration activities of 7 and 8 years old children, this way fostering to enhance children's awareness, exploration and understanding of the living being concept, namely microscopic biodiversity. The context of this research is a PhD project that studies living being concept, using sensors in experimental activities. A case study was developed, in a Portuguese primary school. A set of experimental activities were planned and mediated by the researcher, also responsible for the participants' observation. Photos, audio recordings and the students' registers were collected. Data was processed using content analysis. Therefore, the developed research illustrates the role that sensors can play in developing fundamental knowledge, and competences, bridging the gulf between concrete and abstract thinking. Through teacher mediation, digital microscopic scaffold the abstract observation of the unobservable.

Keywords: senses, sensors, living being, biodiversity, reproduction, science experimental teaching.

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Introduction

Considering a better perception and understanding of the world and the natural environment that surrounds children as the principal goals of the *Environment Study* subject, the concept of living being, in the traditional approach leads to a diverge acquaintance of what it really is, making difficult not only its understanding but more importantly its relation to the ecosystem, biodiversity and reproduction concepts.

The concept of a living being is linked to the concept of biodiversity, which is the perfect cross-cutting theme to help provide real-world contexts and issues that promote critical and creative thinking, citizenship skills, responsible action, and also illustrates the complexity of environmental issues and the fact that there are many perspectives, as well as much uncertainty" (Pitman, Braus and Asato, 1998). This concept is important to the students' conceptual development, "exactly for including complex processes and abstract entities that are invisible with a naked eye" (Caballer and Gimenez, 1993). For this, the appropriateness of this investigation on the teaching of experimental science about the complexity and wideness of the living being, giving emphasis to problem solving, questions or students' everyday phenomena as a way of developing the critical and creative thinking abilities and build high level scientific knowledge (Vieira, Tenreiro-Vieira and Martins, 2011).

"Children's interest for Science is vital to their effective learning, especially to develop their curiosity and confidence to see Science in methodical investigation terms." (Murphy, 2003). So the learning model for Science teaching should be child centred, giving him/her a more active role in the whole process. This presupposition leads to a constructive approach of teaching, where children are involved on the building of their knowledge, allowing the deeper study and therefore reinforcing the significant learning of Science. The resort to Information and Communication Technologies (ICT) works as a facilitator on that constructivist approach. The difficulty on defining living being is an issue. If on one hand it seems easy, on the other hand, and after the microscopy developing, it is revealing a boundary that is difficult to establish.

Sensors can be considered extensions of human senses (Magnani, 2004). In the SOS Abstract research project (Using Sensors and Senses in the Environment to Develop Abstract Thinking), sensors are approached as learning mediators, since they can be used by students to explore natural phenomena in a more motivated and engaged way, extending their thinking and creating multiple representations of their understanding (Hug, Krajcik and Marx, 2005). In environmental education, children can use senses and sensors to observe, represent, and control variables in authentic activities that explore complex concepts while developing children's abstract thinking (Silva, Lopes and Silva, 2013).

The way how to approach the theme, so that primary students can study and understand the complexity of the essential characteristics of a living being, is the investigation problem, having also the aim of enrich their perception of Science and making it more realistic.

To investigate around the concept of living being, it will be replicated a didactic work with the experimental teaching characteristics using ICT (Teixeira, 2012), involving a group of 18 students from the 2nd and 3rd grades, in a public school from the Oporto district.

The following questions are presented as the guide ones for this investigation: a) How to approach the complexity of living being concept? b) In which way the conscience of biodiversity, namely microscopic, will originate a better understanding of the living being concept? c) How can an approach to the complexity of living being concept contribute to children's abstract thinking?

This paper has the following structure: introduction, theoretical background, methodology, results and conclusion.

Theoretical Background

Science Teaching and Learning

Socio-constructivism and Science Learning

Education in Science at Primary School has as main role the promotion of useful and meaningful learnings in opposition to a mere acquirements appropriation (Martins, Veiga, Teixeira, Tenreiro-Vieira, Vieira, Rodrigues and Couceiro, 2007).

The Vygotsky constructivist learning approaches based on work (Murphy 2003), highlight the child's mental implication importance, assuming an active role as agents of their own learning, for this the scholar learning is seen as a process of (re)building that knowledge and the teaching as a facilitator action of the process – socio-constructivism (Murphy 2003; Martins et al, 2007). This approach emphasizes the importance of peers and teachers on children's learnings. The teacher's role is important because besides being a facilitator, he/she would be an active participant, giving orientation, incentive and supporting the children, in a way that can make them part in problem solving activities (Lorenzini, 2004; Murphy, 2003).

Scientific Literacy, Thinking and language

"Scientific literacy refers to scientific knowledge and needed abilities to have access to any desired scientific information" (Murphy, 2003). From this perspective, primary school scientific literacy refers to abilities and knowledge for a basic understanding of Science, meaning that the student should know and use simple but appropriate scientific vocabulary. Vygotsky highlights that language, besides a communicative function, has, also the function on

the constitution of conceptual thinking, which is not innate. A child cannot create concepts by herself. "Concept formation is the result of a complex, where all the basic intellectual functions take part (Pedrancini, Corazza-Nunes, Galuch, Moreira and Ribeiro, 2007).

For a child to reach the true concept, needs to develop the ability of abstraction. "A concept just appears when the abstracted lines are synthetized again, and the resulting abstract synthesis becomes the main instrument of thinking" (Lorenzini, 2004). This is the mental organization way that releases the child from concrete and allows a logical building, of abstract ideas, that acquires their meaning inside of the thinking scheme, becoming language.

The ICT in Science Experimental Teaching

Considering the fostering of motivation and autonomy on students learnings as a goal to teachers (Carvalheiro and Del Pino, 2007), the development of experimental work in teaching Science is crucial, allied to the use of ICT. ICT are going towards a socio-constructivist methodology because motivates children to participate effectively on communication, both, verbal and written, critical on the significant scientific concept building. (Murphy, 2003). The digital microscope is a valuable tool to be used in primary schools but the pedagogical questions associated to the way in which its potential can be maximized, is steel less visible, for not seeing widespread in schools.

Curriculum Framework

The concept of living being appears, implicitly, on the Curriculum Organization and Primary School programs (Ministério da Educação (ME), 2004), on the programmatic block -"Discovering the Natural Environment". This includes the contents related to the basic elements of the physical environment and the living beings existing there. But as can be seen by the objectives preconized to the theme approach on the 2nd grade (ME, 2004), -"Observe and identify some ordinary plants and animals existing in a surrounding environment" – there are no considerations about the existing relations between the different physical environments characteristics and the living beings existing there. The distinction between living and not living beings, worked on the 1st grade is restricted to the comparison of differences between animals and not living objects (Catita, 2007), posteriorly, the mobility factor creates some barriers to the understanding that the plants , such animals , are living beings because both have the need of feed, breath, grow, reproduce and die. In this context, appears in the textbooks a small representativity of the living world, restricted a few pictures of living beings, macroscopically visible, belonging to the animals and plants kingdoms (Mafra and Lima, 2007). As the authors, the researcher consider that "the existence of microorganisms perception, should be emphaticized on the first years of school", however, microscopic beings are referred across the curriculum which is a worrisome aspect. This beings appear in the programmatic block – "The discovery of himself" – only in an indirect way, when the study of the importance of vaccination appears, called 'microbes'. From the pedagogical point of view, this incomplete approach about the microorganisms, can contribute to educational obstacles (Mafra and Lima, 2007).

Methodology

This research uses a qualitative methodology, and integrates an exploratory case study, developed, with a constructivist approach, in the context of experimental science teaching curricular activities, using ICT. The participants are the teacher/researcher, and the class of a Portuguese school, in which she is the teacher, with 18 students (9 of the 2nd grade and 9 from the 3rd grade), seven and eight years old. The children's lack of motivation made it even more necessary the use active strategies and the creation of material resources to arouse the curiosity of children, as well as to keep them focused on the development of practical and experimental work.

In order to plan the didactic activities, the researcher used the concept of Formative Situation. A Formative Situation organizes school epistemic objects (physical situations, tasks, information, experience, resources, etc.), so that students, through intellectual and practical activity, mediated by the teacher, can transform teaching objects in learning outcomes (Lopes, 2004).

The sequence of didactic activities, was centred in the use of sensors namely the digital microscope (USB 400X Mic. – Veho® ROHS CE) (DM), the optical microscope (OM) and the binocular loupe (BL) were used to improve the perception of vision limitations, but above all to prove the existence of a micro-world, and integrates 7 sessions, with an average duration of three hours each. Experiment plans were used for each activity. Since children were 7 and 8 years old, the experiment plans were partially filled (problem question, material and procedures). Before the experiment, the students answered the problem question, using their previous knowledge.

Data were collected using participant observation, complemented with audio recordings, photographs, and also with records produced by children. To analyse the collected data, content analysis was the selected technique.

After the study, students completed a worksheet for verification and evaluation of the activities and of the learning outcomes.

Results (didactic sequence)

In this section, the results of the case study are presented and analyzed, considering the research questions. The sequence of didactic activities took longer than planned and expected, since students became very excited when experimental materials,

especially the sensors, were presented. All students were curious to handle such resources that were new for them.

Session 1: Detection of students' conceptions

The activity was initiated from a semi open questionnaire about the concept of living being and objectified the detection of students' conceptions. It is important to stress that the students referred several animals, macroscopically visible and mostly domestic. Until that moment students should not thought about human beings because they were not referred yet. Concerning the ability of naming all the existing living beings, they were unanimous saying no. At that point they refer to the places they live eg. Africa, savanna, forest, on water, on the air.

When the students were asked about the living being concept, they gave definitions that in the opinion of Sá and Varela (2004), were a tautological animal view – defining as animals without a reference to the human beings. As an example, one of the answers "It is an animal that walks, runs, jumps…"

At this point can be inferred that students associate living being to irrational animal. As these children are in a concrete thinking stage they are perfectly capable of thinking concretely about the animal diversity, but they cannot apply the living being attributes to another group of different beings (plants or humans). Asking them to generalize characteristics of living beings widely increases the degree of difficulty in the understanding of the living beings attributes, with an abstract character that dissociates from the particular situations thought by the students. Consequently, they were not able to do that.

The session ended with four questions that Sá and Varela (2004) used in their study as a pre-test, in order to detect the 1st grade students' conceptions about the living being concept. On table 1 are presented the results of the students' answers.

Table 1: Students' to the pre-test answers (adapted from Sá and Varela, 2004).

QUESTIONS:	YES	NO
a) *Have all the animals got paws?*	7	11
b) *Are the plants living beings?*	14	4
c) *Is the Man (human being) an animal?*	8	8
d) *Do all living beings move?*	12	6

From the given answers it can be stated that: a) not all students answer that all animals have paws, giving as an example fish or snakes; b) only the 3rd grade students mentioned plants; c) 8 students steel have doubts related to the fact of humans being animals; d) not all the students realise that the living beings move, they justified their answers using plants.

Session 2: Field trip to collect specimens of living beings

Before the field trip, all the procedures were explained, namely the importance of the sense organs use, not only to observe thoroughly all around, as stated by Eberbach and Crowley (2009), but also, in silence, listen, and feel characteristic smell of the place.

Bottles and bags were distributed to collect living beings, remembering the importance of returning to their natural habitat. Interested and excited the students provide themselves with tweezers, hand magnifiers and small shovels. The field trip took place as planned, the students took photos, but the most important part was collecting the living beings.

Session 3: Introduction of concepts: Biodiversity and Ecosystem

After detailed and magnified observation of the living beings collected in the field trip as well as analysis in encyclopedia and internet, we have developed the concepts of macroscopic biodiversity and ecosystem.

During the iconic register of the living beings collected, it is noteworthy the difficulty of drawing the correct enlargement, after the BL observation. Tendentiously the naked eye observation was drawn. Contrary the observations done using the DM were a match to the correct enlargement.

Session 4: Are there invisible living beings to the naked eye in the puddle water?

16 students answered no, but 4 said that there are microbes "animals that cause diseases… found in hands… but as transparent living beings, they are everywhere, we don't see them." So they said that we can found them in the puddle water.

After this first answers, a water drop observation took place, apparently clean in BL and OM. Children looked surprised when they noticed the existence of small and different microscopic living beings.

Session 5: Microscopic living beings in the transparent puddle water

Aiming a better awareness of the microscopic biodiversity concept the observations on BL, OM

and DM drawings were used again. At this point, the students' representations (figures 7 and 8) were faithful to the made observations (figures 1 to 6).

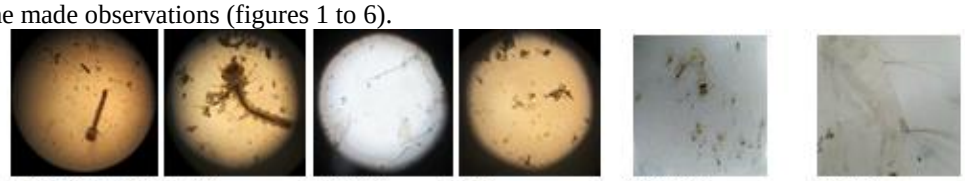


Fig. 1-6–Photos BL: 20x 40X OM: 64X 160X DM: 20X 400X

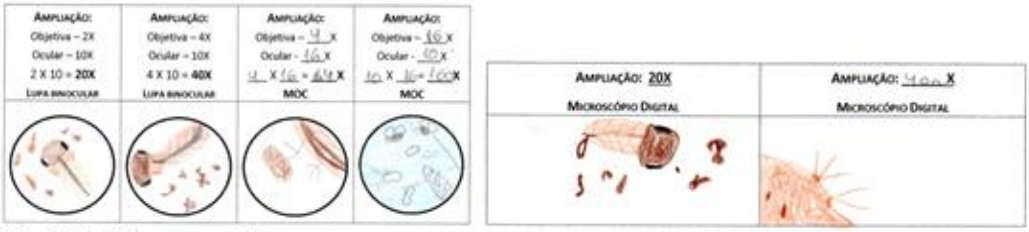


Fig. 7 and 8 – Students' representations.

In the researcher's opinion this results are related to the fact that the perception of the macroscopically visible, already of student knowledge, difficult the conceptual change, (proven by the difficulty in the correct drawing of the macroscopically visible beings enlargement).

Session 6: Cells – structural and functional units of living Beings

After the detailed analysis of the different observed beings' structure, as well as the research readings on the Internet, students understood microscopic biodiversity. In this context, the introduction to the cell concept was given to students. Primarily using an egg (chicken) and after using vegetable (figures 9 to 15) and animal cells observation.

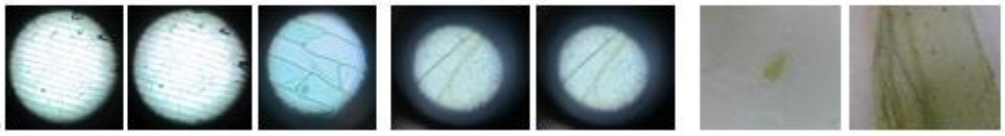


Fig. 9-15–Photos OM: onion 64X 160X 640X *elodea:* 160X 640X DM: 20X 400X

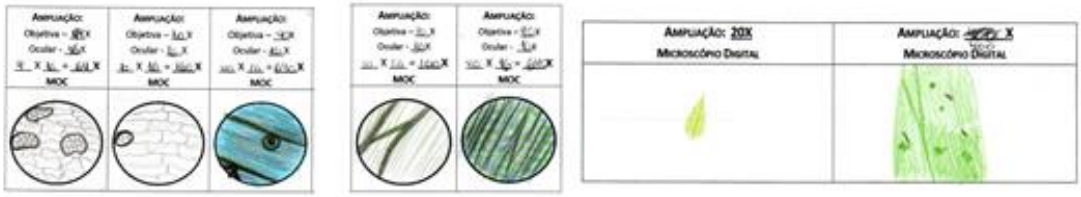


Fig. 16, 17 and 18 – Students' representations.

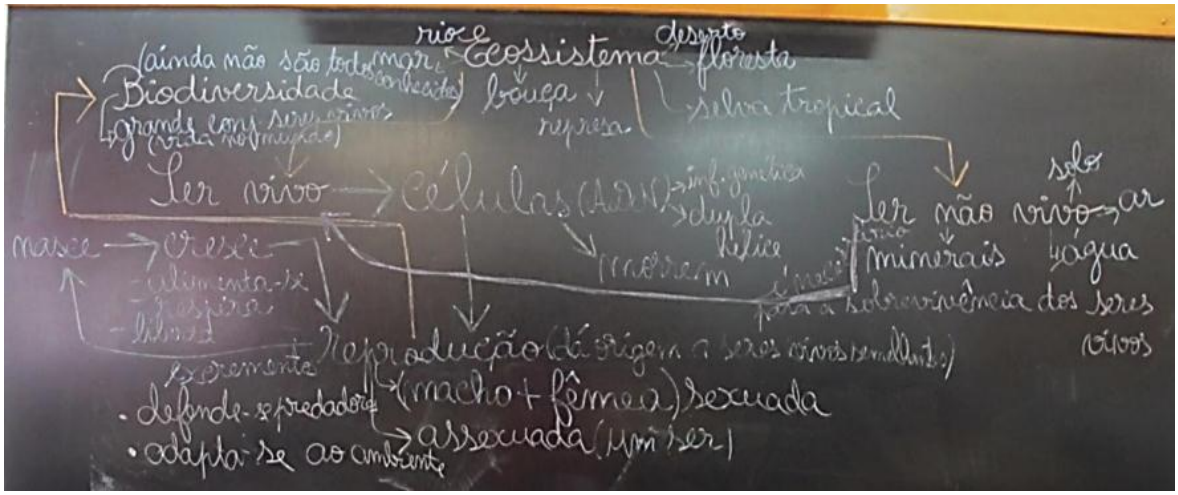
Once again, the students' representations were similar to the observed enlargements both in BL and OM (figures 16 to 18). These structure were unknown to students. As a first observation, was not possible having preconceptions that might change the results.

Session 7: Evaluation

As a way of assessing the students' significant learning and bearing in mind that the conceptual map is an excellent resource, the students were asked to build a national network, a similar activity to the building of a conceptual map, that forces students to structure their thinking and to relate central concepts work throughout this study. It was a slow process.

Students used a lot of different words for each concept. Key words that define the concept of living being making a distinction of not living being were not forgotten.

As picture 19 shows, the established relations between the different concepts, also reveal the development of significant learning, due to the required mental complexity. All students seemed to understand the existent relations between ecosystem and living beings/not living beings, bearing in mind that the living beings habitat is essentially a not living one. The relations between biodiversity and living being as well as living being and reproduction also became clear. It is visible the relation's complexity as shown on picture below.



Pic. 19: *National network collectively built on the black board.*

Considering the quantity and vocabulary used by students, it is easy to notice their development on scientific literacy. Before ending the students' learnings assessment, they were given a post-test. Table 2 shows the results:

Table 2: Students' answers to the post-test (adapted from Sá and Varela, 2004).

QUESTIONS:	YES	NO
a) *Have all the animals got paws?*	0	18
b) *Are the plants living beings?*	18	0
c) *Is the Man (human being) an animal?*	18	0
d) *Do all living beings move?*	0	18

Through the given answers and according to Sá and Varela (2004), the Piaget's view of movement as a prime factor on the progressive differentiation of the living being concept, was not confirmed with this study. The fact that all the students recognized plants as living beings, leads to the conclusion that "this results show that the 4th Piaget's stage of development of the living being concept - animals and animals and plants inclusion on the living being category – is within the reach of children before the ages of 11/12, if properly worked.

Due to the existing relations on the *national networks*, as well as the result of the post-test to the questionnaire (table 2), the stimulation "on an effective way, on building significant relations between phenomena and concepts can be proved" (Ursi, Dessen and Towata, 2010), according to attitudinal and conceptual objectives proposed by curriculum organization and programs.

As a properly conducted practical work, I think that the objectives for its use on the three domains were reached (Martins *et al*, 2007), as seen on the competences developed by students and discriminated by domains below:

Cognitive- Related variables, on comparing and registering the things that became visible on the different enlargements (only possible through the use of DM and OM) – Mentally calculate the enlargement value; - Understand new concepts (biodiversity, ecosystem, unicellular and pluricellular beings,…); - Develop the ability of abstraction, generalization, understanding and mathematical argumentation and logical reasoning elaboration (perception of the existence of microscopic biodiversity; understanding reproduction as a phenomena that allows the natural conservation of species and consequent biodiversity maintenance).

Affective – High motivation; - Students established long dialogues, and even heated discussions between themselves concerning to the living beings characteristics; - Developed a more enthusiastic and critical position , not only about their own ideas but also to defend themselves from contrary opinions.

Procedural – They contact directly with phenomena and unknown situations (field trip; using lab tools; microorganism observation; strict

implementation of the procedures in experimental protocols); - They were able to do a vast numbers of experimental activities; - Manipulated different measuring instruments (BL, OM, DM); - Observed and described a good deal of situations in order to draw conclusions.

Results analysis

At the beginning of the activities, children didn't mention microorganisms, when asked to give examples of animals. In the end, they talked to each other about their characteristics.

All children were able to correctly register the living beings, which they didn't know before, observed in the transparent puddle water with the binocular loupe, and with the digital and optical microscope. The same happened with the observation of the onion bulb epithelium cells and of the cells of the leaves of an *elodea*.

Nevertheless, they failed in drawing the observations of macroscopically visible plants and animals, when using the binocular loupe. Even seeing the microscopic image, children draw the more familiar macroscopic image. This shows that it is more difficult for them to change an already preconceived image to a new image.

However, 12 children were able to correctly draw the observations of the same macroscopic living beings, when using the digital microscope (magnified 400X). Perhaps because the image is easily observed (in the computer screen) and they could see the living beings simultaneously with and without the digital microscope.

During assessment, children emphasized the magnifying power of the digital and optical microscope, showing to prefer using the digital one, since "it was easier to focus". They mentioned that the microscopes make the invisible visible, and that they have observed diverse microscopic living beings.

Conclusion

The use of the digital microscope helped children in understanding the magnifying power, since they could see the macroscopic living being (Silva, Aboim, Teixeira, Pinto, and Pereira, 2016), simultaneously with (in the computer screen) and without (naked eye) the magnification.

Using the digital microscope, children could observe the microscopic biodiversity in a sample of puddle water, apparently clean. This activity engaged children in using the digital microscopic to observe diverse materials (Teixeira, Silva and Gayoso, 2015; Silva, Aboim, Teixeira, Pinto and Pereira, 2016).

The use of the optical microscope to observe animal and vegetal cells, helped children to perceive the cell as the unit of living beings. The students' drawings confirm their understanding of that notion. Children showed difficulties in relating the micro and macroscopic view of the macroscopic living beings. These results were consistent with previous investigations (Teixeira, 2012), in which the continued use of the digital and optical microscopic supported children in overcoming such difficulties.

The use of new words and expressions by children, as well as the conceptual relationships designed by children in the notional network, evidenced the development of children's scientific literacy.

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