Constructionism, Complex Thinking and Emergent Learning: Preschool Children Designing and Programming

Eleonora Badilla-Saxe *eleonora.badilla@ucr.ac.cr*
Academic Evaluation, University of Costa Rica

Abstract

In this short paper I report, from three interacting perspectives, a research experience about learning in a constructionist environment. From one of the perspectives, preschool children learn while they collaborate in designing relevant contexts (microworlds) and constructing and programming behaviours for physical models, all using reusable materials. On another, two groups of my graduate students from the School of Teacher Education at the University of Costa Rica learn while planning a constructionist approach to support children in the construction and programming of their microworlds and creatures; identifying, as well, evidences of their learning according to the official preschool curriculum in Costa Rica. From yet another perspective, while supporting my students with their research project and challenging them to go beyond what has been planned, I learn about complex thinking, and learning as an emergent phenomenon that transcends what has been foreseen in the curriculum.





Keywords

constructionism, microworlds, objects-to-think-with, preschool, robotics, design, emergent learning, complex and eco-systemic thinking.

Chapter I Conceptual Framework

I.1 On Constructionism

Constructionism is Seymour Papert's pedagogical proposal, derived from the Constructivist theory of Jean Piaget. Papert's central idea is that learners should play an active role in their learning. Therefore, the purpose of education would be to empower them so that they may assume this leading role, designing their own projects and building their knowledge. In that regard, he says: *"…the best learning will not come from finding the best ways in which teachers can instruct, but from providing the students with the best opportunities for them to construct"* (Fabel, 1990). This is the premise that will rule the learning process from the constructionist approach, which supposes that people possess a natural ability to learn through experience, creating mental structures that organize and combine the information and experiences acquired through daily life. In Papert's opinion, knowledge construction often occurs in a especially fruitful manner when the person learning is consciously involved in a more public construction, that is, a construction that can be exhibited, discussed, examined, proved, or admired. This public construction ranges from a sand castle or a Lego house, to a webpage or a computer program (Fabel, 1990.). It is in this sense that Papert warns that it is not enough to suggest to students they take charge of their learning by assuming an active role, but rather that the learning environment and tools made available to the learners are fundamental. That is to say, society and culture are largely responsible, for they must provide the resources needed to learn. In his opinion, computers are particularly powerful tools, since he starts from the hypothesis that much of what we now consider too formal or abstract to be understood at early ages, will be learned more easily when the learners perform within a computerized rich world. That is why he focuses on the process of inventing objects-to-think-with within a new kind of learning environment, which supposes the interaction between children and computers. Thus, he affirms that *"… we can free ourselves from the superficial and pragmatic considerations that once ruled with regard to what knowledge should be learned and at what age"* (Papert, 1987, p.69). Papert is especially interested in the role played by physical objects on thought development, which is why he believes that an object-to-think-with may be used by the learner to think about other things, while reflecting on the construction of the object. He affirms that we create our knowledge of the world by creating objects, experimenting with them, modifying them, and studying how they operate. In keeping with Piaget, Papert considers that the learning process cannot be removed from the lesson itself. In this sense, the objects-to-think-with cannot be removed from the learning process itself, nor from the content learnt, thus becoming an inherent part of knowledge construction. Regarding the environment where knowledge is constructed supported by the objects-to-think-with, he developed and coined –together with Marvin Minsky– the concept of "microworld", as a model to create representations of an immediate reality over a subject matter, which will be refined or polished by the students, emerging from a starting point that allows them to create their own "extensions". In that sense, a microworld constitutes a tiny *constructionist* world, wherein the learner can explore choices, prove hypothesis, and discover facts that are true in relation to such world. It differs from simulation in the fact that the microworld is a real world (even if virtual), instead of just a simulation of another world.

I.2 On Complex Thinking

As the sociologist Edgar Morin (2008) points out, the kind of thought in which knowledge is fragmented, compartmentalized, monodisciplinary and quantified leads to a blind intelligence, insofar as the normal human aptitude to connect knowledge is sacrificed to the no less normal aptitude for differentiating it. He alternatively propounds complex thinking as a method to know and know the knowing process. Complex thinking is the organizer of the organization we use to represent the world; it is part of our thoughts, our ideas, and our scientific theories. In Morin's opinion, (2004) complex epistemology is the knowledge of knowledge, and knowledge is a "spiral adventure" that has a starting point but no end, tirelessly performing concentric circles. However, it is important to clarify that complexity does not lead to the elimination of simplicity, nor does it reach *completion.* Regarding simplicity, Morin says: *"… while simplifying thinking disintegrates the complexity of what is real, complex thinking integrates, as far as possible, the simplifying ways of thinking; rejecting, nevertheless, the mutilating, reductionist, one-dimensional and finally blinding consequences of a simplification deemed a reflection of what could be real in reality"* (Morin, 2006). And concerning *completion,* he says*: "Certainly, the ambition of complex thinking is to account for the articulations between disciplinary dominions disjoined by dispersing thinking (one of the main features of simplifying thinking); the latter isolates what it separates, and hides everything that rebinds, interacts, interferes. In this sense, complex thinking aspires to multidimensional knowledge. But knowing, from the start, that complex knowledge is impossible: one of the axioms of complexity is the impossibility, even theoretical, of an omni-science"* (Morin, 2006).

In that sense, we may explain to ourselves complex thinking based on the etymology of the term "complexus", understood as that which is woven together or conjointly interwoven, and in that context, the emergence or the emergent of the interrelations between parts and properties will become relevant to diverse authors and in different fields. In the Wikipedia Free Encyclopedia[1], we find that emergence refers to those properties or processes of a system not reducible to the properties or processes of its constituent parts. It is closely related to the concepts of self-organization and supervenience, and defined in opposition to the concepts of reductionism and dualism. One of the most common examples of an emergent phenomenon is the mind: it emerges from the interaction distributed among diverse neuronal, corporal and environmental processes, but it cannot be reduced to any of the components that participate in the processes. From the epistemological perspective, emergence refers to the impossibility of the observer to predict the appearance of new properties on the system in question. Enrique Margery (2007) affirms that the emergent is an unexpected answer or reaction, not anticipated, produced as a result of the interaction between the parts of a whole.

For our purposes, we accept that learning is an emergent phenomenon. It arises from the interaction distributed among different processes –neuronal, corporal, emotional and environmental– but it cannot be reduced to any of the components that take part in the processes. In that context, we should understand that most learning is unexpected, often impossible to foresee, and that the contents of those learning are both simple and complex, although the complex ones are not mere aggregates of the former.

[1] http://es.wikipedia.org/wiki/Emergencia_(filosof%C3%ADa) recovered on June 29, 2007

We acknowledge some reference points posed by the Brazilian researcher Maria Candida Moraes (2008), which guide our steps towards understanding learning in constructionist environments as an emergent phenomenon, unforeseeable and unrepeatable. In Moraes' opinion:

- Complexity is dynamic and therefore, processual. Dynamic processes are unforeseeable and creative, with the ability to go beyond the known or foreseen horizon.
- Each experience is unique, does not repeat itself and nontransferable, since time does not act retrospectively over matter, and neither does the present over the past. This understanding warns us about the importance of being aware of the important moments in life, both in the personal sense as in regard to knowledge and learning.
- Phenomena are multidimensional, and perceiving their multi-causality and multiplicity of effects is necessary to gain a more appropriate understanding. To think in a complex way is to understand relations, connections and links.
- There is no single objective reality independent from that which is observed, but rather multiple realities, and which of those realities will be revealed depends entirely on the observer.
- There are important and different types of knowledge. The interpretations of each individual concerning reality are different.

Chapter II Learning in a Constructionist Environment: Preschool Children Designing and Programming Creatures

The research experience "**Learning in a Constructionist Environment: preschool children designing and programming creatures"** was carried out at the University of Costa Rica, in 2005-2008. The process was developed in two interrelated stages, as the final project of graduate students to apply for the Licenciate degree on Preschool Education. The project was a reflective practice, where the students-researchers viewed themselves as part of the process, particularly reflecting upon their own learning process. In my case, as researcher director of both stages, I also considered myself as part of the process, reflecting as well upon my own learning process; thus, I present my own conclusions in this report, concerning the experiences I lived with my students and the preschool children.

A Constructionist methodology: In the first two years of the research, a group of students from the Preschool Education degree course designed and tested a constructionist methodology, so that 5 and 6-year-old children would learn in a creative and meaningful way, using physical-digital materials to build programmable creatures. The building of these programmable creatures became a means for learning, and not the end itself. The activity of the children was conducted in the context of a preschool education classroom. The children called their learning activity ***El divertidor***, "The Entertainer". Using cardboard boxes and disposable materials, they assembled, inside their regular classroom, what we call (based on Seymour Papert)[2] a microworld: a haunted house, a castle, a space ship…

[2] Seewww.papert.org, recovered on August 1, 2008.

And for that context, they designed, built and programmed a creature: a guardian monster, a flame thrower dragon, or a Martian detector (an object-to-think-with). They only used the digital materials strictly needed, making the most out of plenty of disposable and easy-to-get material. Collaborative work and family involvement were promoted. The constructionist methodological proposal to ensure a learning environment where preschool children would learn how to build programmable creatures (objects-to-think-with) within a microworld context, included the following components, not performed sequentially but recurrently.

1. **Social Interaction**

Figure 1
Social interaction must be an important part of a preeschool constructionist learning environment

2. **Constructing a physical microworld**

Figure 2

Figure 3

Figure 4

Using a large cardboard box and colored papers, watercolors and other building materials, the children designed and created their microworlds: a castle, a bus, and a haunted house.

3. Predicting the creature's behavior with "natural language"

 *Figure 5*	*"There is a monster in the haunted house. If someone enters, the monster spins many times to frighten him/her."*

4. Exploration of physical-digital material

Figure 6

The children explored physical-digital materials created by the teachers. They discovered the digital materials that make programming feasible.

5. Programming the creature by way of artificial language

 *Figure 7*	 *Figure 8*
Exploration of language programming icons, using printed cards	*Programming the "monster" in the computer using programming language*

6. Comparing natural and artificial languages: verification

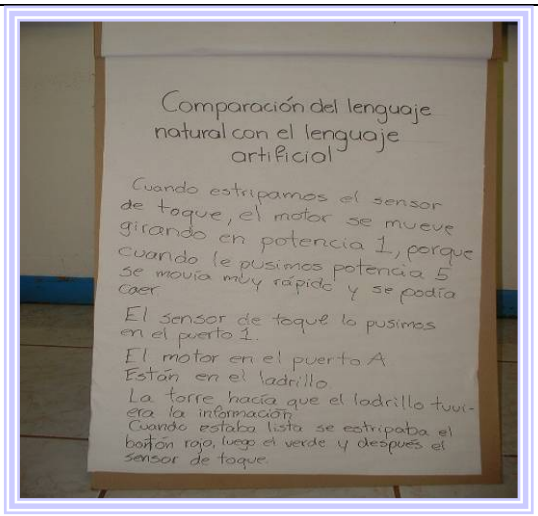

Figure 9
Comparing languages

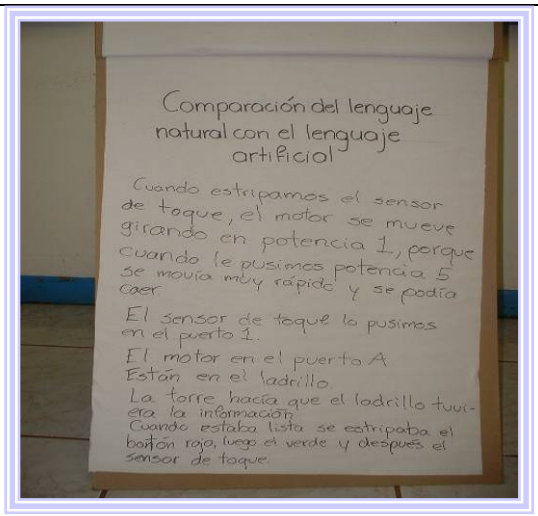

Figure 10
Comparing languages

During this stage, and in a process of self-assessment, the children verified whether the programming of their creature by means of digital language corresponded to the behavior they had foreseen with natural language.

7. Exploration of the creature's behavior in the microworld

Figure 11
The creature in the microworld

8. Reconstruction of the process

Figure 12
What happened? How did we do it?

The children immersed themselves in the microworld, in order to export the behavior of the creature they had designed and programmed. In other words, they became part of the microworld. They had the chance to test their programming, assess whether it answered their expectations, and return to the programming process in order to modify it.

For instance, the programming of the "monster" actually worked, since the moment the light sensor was activated, the motor started and the creature revolved. But it did so too fast, and was finally thrown into the air. The children had to go back to the programming stage in order to modify it, identify what criteria should be changed, test their new programming and repeat the process, until they were satisfied with the monster's behavior. Self-assessment was encouraged, both in the stage of exploration as in the reconstruction process.

With regard to this first stage of the research, and to complement the conclusions of the students-researchers concerning the process with the children, I can ascertain that:

By definition, learning is an emergent phenomenon, and according to Maria Candida Moraes, the learning environment should be: *"… enjoyable, rich in meaningful and off-key elements, and capable of rescuing the joy and pleasure of learning…* It must promote *the construction of knowledge, the creation of identities, and the development of cultural and social practices, holding complexity as one of its main foundations."*

And with regard to the digital technologies, I agree with Seymour Papert when he says: *"When we think about technology in education, we must not expect it to have an effect. We should rather reflect on the opportunity offered by technology to rethink what learning is, to rethink education."*

Emergent Learning: During the last two years of the research, another group of students-researchers of the degree course mentioned above put into practice the design of a learning environment, enjoyable and rich in meaningful and off-key elements, as well as the methodological proposal previously described, while trying to identify, at the same time, the mathematical skills and social conducts displayed by the children as they designed, assembled, programmed, tested, corrected, explored, discussed, built, played, thought, doubted, reflected and had fun. This time, the students suggested this assessment (besides the self-assessment that the children would do later on), since they deemed important to prove that, by using these new technologies, the children could also learn the contents included on the official curriculum for the preschool level in Costa Rica. This second part was conducted at a public kindergarten located in a semi-rural area, throughout five learning sessiones.

On these five sessions, the 5 and 6-year-old children showed, in July (in half the time scheduled by the country's official school calendar), 53 of the 68 mathematical skills anticipated by the Syllabus for the Transition Cycle (preschool) enforced by the *Ministerio de Educación Pública* MEP (Ministry of Public Education), in Costa Rica for the entire school year. In the social sphere, the children showed social conducts predicted by the aforementioned Syllabus: cooperation, expression of likes and preferences, and tolerance to frustration, among others.

Nevertheless, I had suggested to the students to not limit themselves to observe whether the children showed the mathematical skills and social conducts included in the official Syllabus, but to observe signs of other learning as well.

Observing the children work, and using regular evaluation instruments for preschooler, they identified, among others, the following:

- **Solving exercises and problems within time limits** (included on the Syllabus for 5th grade);
- **Time estimation and measurement, concept of movement, implementation of concepts such as speed, velocity, distance, movement and force** (7th grade);
- **Power** (10th grade).

In the social sphere, they showed social conducts not included in the official curriculum for preschool levels, for instance:

- **Working as a team;**
- **Collaborating on the development of a project;**
- **Respecting the choice of the majority.**

Chapter III Lessons Learned

To complement the conclusions issued by the students-researchers, I came to the following conclusions:

- Being that learning is an emergent phenomenon, it is important to bear in mind that the learners will construct other knowledge not necessarily related to the purpose of the curricular design;
- Being that learning is an emergent phenomenon, it is important to bear in mind that the students will express simple and complex knowledge, and that the complex will not be mere aggregates of the former; therefore, it is important to explain the relations and connections that exist amongst what was learnt;
- In a constructionist environment, rich in meaningful experiences and where the students are allowed to take an active role in their own learning process, unforeseen knowledge will emerge; therefore, teachers and researchers should be aware of this reality, in order to detect and record (not necessarily grade) the knowledge resulting from the multiple interactions that intercross within a learning environment.
- Being that the circumstances for knowledge verification are not replicable, and that the different interpretations of the subjects on one and the same reality should be taken into account, it is important to understand that, in each situation, different knowledge will emerge.
- If a constructionist environment is allowed, wherein learners take charge of their own process, the use of digital materials in learning promotes the building of concepts at earlier ages.
- From the perspective of education in general, and training of teachers in particular, these conclusions have enormous implications concerning the way we view our students; the manner in which we should help teachers so that they really “see” their students; the approach used to design curricula and study programs. And above all, it forces us to rethink our beliefs concerning learning and assessment of learning.

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