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Teaching as the emergent event of an ecological process: Complexity and choices in one-to-one programmes

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Abstract

The article argues that the ecological approach can offer a viewpoint that comprises more educational complexity. If we accept that the observer and object of observation are in a constant relationship; that technology, context and culture are constituting forces of knowledge production; and that theory/practice is another binary divide to overcome, we are forced to address the intertwined emergence of teaching and learning as part of a co-evolutionary process. As part of ecological pedagogy, communication choices focus on feedback, interconnectedness and in-between-ness among living and non-living organisms. By drawing from the encounter between the complex perspective of Gregory Bateson (1972) and the thinking of media ecologist Marshall McLuhan (1964), this article focuses on communication choices in teaching. It presents a comparative study on one-to-one programs in schools in Italy and Brazil, and shows the importance of existing connections and communicational exchanges between the elements of a dynamic system.

Keywords: Teaching; Emergence; Media Ecology; Complexity theory; One-to-one programmes.

Introduction

Contemporary education sees two contradictory movements at work: one involving an increase in complexity and diversity and another involving a reduction in complexity (Lenz Taguchi, 2010). The first movement is related to human togetherness in the midst of globalization, multiculturalism and growing inequality (Apple, 2004; Osberg & Biesta, 2020). The latter one offers political solutions often focused on technologies or innovative methods (Pischetola, 2019), and conceives of teaching as mainstreamed actions based on tools and universal standards (Gorur et al., 2019). Biesta and Osberg (2010) describe the discourse surrounding education as one of “control”, as part of which practices and processes try to achieve a perfect match between “input” and “output”. When we observe technology-driven policies in education, this causal relationship is even more evident (Heinsfeld & Pischetola, 2019; Oliver, 2011). Teaching practices and learning outcomes are supposed to be

transformed by the presence of technological devices, while other variables - teacher training, socio-cultural factors, geopolitical situation, and educational traditions, to mention a few - are ignored or considered as secondary for teaching innovation. The ecological framework can question this deterministic view, as it opposes a relational view of the classroom.

In this paper, we take a step toward a non-descriptive use of the ecological framework for education (Hecht & Crowley, 2019; Osberg et al., 2008). Our proposal is to address the technology-mediated teaching process through the lenses of Complexity theory, which offers analytical tools from the fields of biology, anthropology and communication. We will especially look at the concepts of feedback, non-linearity and emergence, which relate to the way communicative choices shape the environment, leading to a landscape of uncertainty, openness and learning. These contributions will be placed in dialogue with the field of Media Ecology, drawing on a parallel between Gregory Bateson and Marshall McLuhan.

This paper is divided into two sections. In the first one, we elaborate on a fruitful ecological/complex approach for educational research. In the second section, we present empirical evidence from a comparative research study on one-to-one programs, undertaken in Italy and Brazil between 2009 and 2012. Data were collected through a one-year ethnographic study in each country, with participant observation, interviews with teachers, and focus groups with pupils.

An ecological approach towards complexity in Education

The ecological perspective has highlighted the mutual dependence of the individual and the environment, which overcomes the dualistic worldview of divides between mind and body, subject and object, observer and observed, and changes the way we look at knowledge production. Denying the separation between mind and matter, Bateson (1972, 1986) argues that we are subsystems or integral minds, that is, we are always part of a larger system, which he calls ecology of mind. According to the author, the view of a systemic nature, in which organisms and the environment constitute a single co-evolutionary whole, is founded on the idea of communicative unity between parts. This connection is achieved through an “elementary information unit” that connects organisms with each other and with other components of the environment they live in. Such a unit consists of information, which for Bateson (1972, p. 460) is the “difference that makes a difference”. Our sensory system operates with events, which we call changes, which urge the organism to make a change itself.

In the last two decades, the ecological framework has been increasingly employed in educational research to describe learning and teaching practices (Barron, 2006), organizational and structural change (Barab & Roth, 2006) or educational policy (Weaver-Hightower, 2008), among other topics. This approach can provide educational research with information about how communication occurs between individuals, systems, biological entities and the physical environment. From a multidisciplinary perspective, it shows that social and psychological aspects intertwine with non-living matter and living organisms (Berthoz, 2009) in a communicative ecology of mutual affect (Bateson, 1972). However, many educational researchers have used ecology merely as a descriptive metaphor. Fenwick (2009) argues that the use of abstract concepts to represent human processes and organizations is misleading, as it does not ground the data analysis in a practice-oriented tradition. Moreover, she points out that the focus on relational aspects of educational ecology has raised a problem of ethical responsibility. It definitely maps existing phenomena,

but without touching upon values and issues related to power distribution. Osberg et al. (2008, p. 205) say that open systems (reality) cannot be represented by closed systems (models) as “all representations of complex phenomena ultimately betray their object”. They call for a more ontological focus on education. Along the same line of thought, Davis and Sumara (2008) suggest that the concept of ecology (or ecosystem) could be used to frame an educational theory to offer a more realistic approach to the classroom. Hecht and Crowley (2019, p. 1) also argue that acknowledging relationships between elements is not enough “to take seriously the notion of learning” and suggest drawing more heavily from ecologists. In fact, as Mason says (2008, p. 38), complexity theory can help look at “individuality”, the “apparently marginal”, and “the seemingly trivial accidents of history”.

Despite a growing interest on the part of educational research in the ICT integration process, the ecological approach is not often used (Oliver, 2011; Pischetola & Miranda, 2019). Research by Jenkins et al. (2006) represents an exception, as it analyzes a wide set of elements which contribute to a “participatory culture” within the school system. This is described as a culture that “absorbs and responds to the explosion of new media”, which includes “ludic forms of problem solving, identity construction, multitasking, ‘distributed cognition’, and ‘transmedial navigation’” (Jenkins et al., 2006, p. 8). Digital games have also been studied from an ecological standpoint. Here, the idea of ecology is used to understand how different elements (such as codes to interpret social practices, rhetoric or aesthetics) interact with the game world (Salen, 2008). Among the first researchers to inquire on the role of games in learning, James Paul Gee (2007) argued that game play produces good learning, through a strong sense of ownership and agency within the individuals of a networked community. Ito et al. (2008) add that any modification in the media ecology has important implications for learning. Nonetheless, in these examples authors again do not address the complex dynamics that contribute to emerging patterns of the participatory ecology, and use ecology mostly as a representative/metaphoric model.

It is our purpose to explore a deeper understanding of the ecological approach, beyond its most common use in education. Bearing this in mind, we propose adopting a Complexity theory framework to analyze technology-mediated teaching practices. In the following section, we present a brief history of this perspective and its most relevant concepts.

Complexity theory and the role of choices

According to Le Moigne (1996), Bachelard was probably the first scientist to legitimate complexity as an ideal epistemological stance for a non-Cartesian approach to science. “There is no simple idea, because a simple idea is always inserted, to be understood, in a complex system of thoughts and experiences” (Bachelard, 1934/2003, p. 152).

From the mid-20th century onward, complexity theories have been developed through different disciplinary domains. The first contributions have arisen from Cybernetics, an interdisciplinary field that originally gathered scientists like Norbert Wiener and John von Neumann, from mathematics; Claude Shannon and Julien Bigelow, from engineering, and Warren McCulloch, from neurobiology. At this time, the concept of *feedback* was introduced, to explain how a system operates by adapting to the environment. A second generation of complexity theories comprised contributions from Systems Sciences and Biology (von Bertalanffy, 1950; Bateson, 1972), Computer/Engineering Sciences, with the newborn field of Artificial Intelligence (McCarthy, 1989) and Thermodynamics (Prigogine, 1969). In this phase, the research focused on the processes of *emergence* and *non-linearity* of dynamic processes.

Since the 1980s, a third generation of complexity theories has developed from Anthropology of knowledge (Morin, 1980, 1991), Epistemology (Le Moigne, 1996) and multidisciplinary studies on Complex Adaptive Systems understood as organic, ecological or socially complex phenomena (Helmreich, 2004). This last phase has shifted the focus from “organized complexity” to “organizing complexity” (Alhadeff-Jones, 2008), meaning that the researcher’s action and involvement with the research object has been reintegrated as part of the object itself. This understanding of complexity reintroduces uncertainty and lack of control (Le Moigne, 2003), and is valuable ground for education.
Some of the concepts that have arisen from this brief historical excursus of Complexity theory are worth a closer look, as they can be used as categories of analysis for educational research. These are feedback, non-linearity and emergence. As we will see, they are all intertwined with the role of choices.

Feedback

With the concept of feedback, Cybernetics brings to Social Sciences a new approach to comprehend the communication process. According to the idea that every "effect" retroacts on its "cause", the notion of circular system changes the linear explications of phenomena (Winkin, 1981). Bateson (1972) used the concept of feedback to observe the conditions and possibilities of social system maintenance or adaptation. He explained that change depends upon feedback loops, which are classified in positive and negative ways. The mechanism of positive feedback amplifies the distribution of small successive events that create large perturbations in the system, which can eventually take the system towards destruction/recreation. With negative feedback, the system is able to return to stability through successive self-corrections, as interaction loops can inhibit or detract changes. In educational processes, the mechanism of positive feedback can help to destabilize established models (Fenwick et al., 2011). However, like a homeostatic system, the school was built to resist change by turning complexity simpler. For Berthoz (2009), simplifying complex processes means opting for choices that can dissolve system complexity and gain control and order. According to Osberg and Biesta (2010), complexity in education can be reduced by limiting the number of variables or by lessening the ‘recursivity’ of the system. This action is related to power structures and strengths, but also to corresponding individual choices at each step.

Non-linearity

In 1994, the winner of the Nobel Prize in Physics, Murray Gell-Mann, described the complex ecosystem structure as “a branching tree with probabilities, with accidents at the branchings”. As each accident occurs, a set of choices appears to the system, displaying multiple possibilities for change. The result is a continuous state of uncertainty and unfolding configurations. Evidence from different disciplinary fields confirms the relationship between complexity and difficult choices. In economic literature, for example, the more complex an alternative is, the less probability it holds to be selected (Sonsino et al., 2002). In fact, perceived uncertainty plays a key role in the process of consumers’ decision making (Muthitachareon et al., 2014). In psychology, complexity aversion has a connection with cognitive efforts (Hu et al., 2007), as too numerous or too complex choices relate, for example, to de-motivation (Katz & Assor, 2006). In education, we find an interesting body of literature focusing on teachers’ choices and risk perception (Le Fevre, 2014). Research on

ICT integration in education by Howard and Gigliotti (2015) shows that successful teachers' strategies to cope with uncertainty include a risk-taking attitude and experimenting without fear. Ultimately, non-linearity in the classroom ecosystem reminds us about what Paulo Freire (1996) suggested teaching to be: not an act of control, but a way to enhance students' possibilities for learning autonomously and, therefore, existing as subjects.

Emergence

The core notion of emergence refers to the idea that "the whole is greater than the sum of its parts". In a complex system, new properties and behaviors appear, which are not encompassed in the system's constituent parts or initial conditions (Morowitz, 2002). Emergence is unpredictable, as it depends on the contingency of the variables and on the unique way interaction between the parts occurs (Capra, 1996). In a nutshell, emergence shows that the behavior of an ecology cannot be reduced to a system of rules (Cilliers, 2001), as in a linear understanding of a process. New emerging "entities" that come into being cannot be accessed and analyzed through instrumental methods. For Davis and Sumara (2008, p. 42), the notion of emergence questions the assumption that "the locus of learning is the individual". In fact, learning occurs in complex unities, such as ideas, projects and understandings that are produced collectively. As Fenwick et al. (2011) underline, some authors would consider emergence and learning as synonymous. According to Bateson (1972, p. 287), "the word 'learning' undoubtedly denotes *change* of some kind". Systems develop according to recursive and emergent operations, and learning is evolution of the system itself. He understands different levels of learning as follows: level 0 – it is a simple receipt of information from an external event; level 1 – it is a change in specificity of a response by correcting the errors of a choice within a set of alternatives; level 2 *learn to learn*) – it is a corrective change in how the sequence of information is received; level 3 – it is a corrective change throughout the system of information sets . For the purpose of this paper, we will focus on the idea that emerging educational change (and related learning) becomes possible by virtue of connections between elements and choices taken at every moment.

Complexity Theory meets Media Ecology

From an ecological perspective, it is important to study how different configurations of technologies interact/interfere with our perceptions of reality and result in our communicative choices. In this section, we will try to place in dialogue Marshall McLuhan's perspective with the thinking of Gregory Bateson.

In 1964, McLuhan proposed an ecological view of media, humans and society, and argued that we experience media-as-environments through sensory effects and transitions from one medium to another. By shifting attention from the "obvious figure" to the "hidden ground" (Molinaro et al. 1987, p. 478), McLuhan points out that full meaning of a figure - be it an idea, an institution or an event - can only emerge from its situated context (Logan, 2011). However, the ground (or environment), despite being invisible, is not simply a "container" (McLuhan, 1969). Using one of his puns, McLuhan (1995) declares that his interest is not in media "transportation", but rather in media "transformation". One important point of his lucid analysis is that media are not only platforms that transmit information, but they *are* information themselves (Fuchsberger et al., 2013). McLuhan (1964) also considers that each medium creates a totally new human environment. Electronic media affect human

experience through their active quality (McLuhan & Fiore, 1967), and we might say that digital media provide an even more immersive experience through their multisensorial and multidimensional interplay (Logan, 2010). Based on this view, we recognize that Media Ecology has a foundation in biology. Logan (2007) proposes that language, culture and media can be treated as organisms in that they are emergent phenomena. Moreover, any communication process can be understood as learning, through an ecological approach (Bateson, 1972). Thus, we understand that the biological foundation of Media Ecology is based on two elements: (1) the logical levels of communicative interaction and (2) the ontological fusion of technology and humans in communication ecology.

To consider the logical levels of communicative interaction in the Media Ecology approach, we refer to the concept of codification (Bateson, 1972; Ruesch & Bateson, 1951). For Bateson, the communication process involves interaction between information at different logical levels, from the most basic (non-living systems) to the most complex (living systems). At all levels, this process depends on the exchanged cues and propositions that define the relationship between communicators and codification. Thus, codification is defined as "substitution of one type of event for another, such that the event substituted shall in some sense stand for the other" (Ruesch & Bateson, 1951, p. 169). On one hand, the meaning of a message is an emergent process that depends on learning about methods of coding. On the other hand, the coding system is considered culturally conventionalized (Bateson, 1972). Invoking the notion of figure/ground, Bateson (1972, p. 194) argues that "This double framing is [...] not merely a matter of 'frames within frames' but an indication that mental processes resemble logic in *needing* an outer frame to delimit the ground against which the figures are to be perceived". As such, we reckon along with Logan (2011) that the ecological approach can be an interesting contribution to think about the relationship figure/ground proposed by McLuhan (1969), as it assumes the ground (context) and the figure (meaning) as being emergent and complex processes.

The second element that allows us to root Media Ecology in biology is perceiving the ontological fusion of technology and humans in communication ecology. Reflecting about Bateson's contribution to Media Ecology, Strate (2013) claims that "understanding our technologically modified and technologically mediated environment requires what Bateson termed an ecology of mind" (p. 205). Mary Catherine Bateson (1994) and Charlton (2008) also acknowledge that the epistemological understanding of the ecological mind is impregnated with an ontological perception, despite the fact that materiality in Bateson's view is less debated by literature. Strate (2013) suggests that when we equate the logical levels of communicative interaction with the idea of medium as message, as proposed by McLuhan, we can infer that "the message of the medium (as opposed to its content) is a form of metacommunication" (p. 203). Upon resuming McLuhan's idea that "the medium is the message" (1964), this comparison broadens Bateson's initial conception of coding - which focuses on the communicative exchange between individuals - to include the media technologies and materials themselves. In this way, it is interesting to observe how technology constitutively reshapes our collective situated, mutual awareness and multisensorial stimuli that are necessary for communication to occur.

Research

The study presented here was undertaken between 2009 and 2012. It examined one-to-one programs implementation in schools in two different countries: Italy and Brazil.

The goal of one-to-one programs was to provide pupils in early years at primary schools with a personal laptop and to make them develop new skills by self-learning. The first worldwide initiative of this kind was named One Laptop Per Child (OLPC) and was launched in 2005 by Nicholas Negroponte from the MIT Media Lab, with the ambitious purpose of closing the digital divide globally.
The OLPC laptop, called XO, was designed to run open source software and meant to trigger an innovative learning. The classic Windows/Apple subdivision of content into folders was replaced by a "logbook" proposal: the operating system automatically saved users' activities in chronological order, associated with icons to represent their category (e.g. text document, game application). Moreover, the XOs could connect with each other through a self-generated wireless network. In its essence, the XO was not designed as an office computer, but as a learning environment for children (Serenelli & Mangiatordi, 2010). Pupils also liked its hardware, as it looked different from a "big computer": it had a soft keyboard and wi-fi antennas that children found similar to "ears" (Pischetola, 2011).
Since 2008, western countries were also able participate to the OLPC program through the "Give one-Get one" initiative, through which half of the acquired laptops were donated to a developing country. In 2009, Italy implemented it with 700 laptops in Brescia region (Northern Italy), and donated the same amount of laptops to Ethiopia. Our ethnographic research took place in the same year, with aone-year immersive fieldwork study at four primary schools.
In Brazil, a national adaptation of the OLPC program, named Um Computador Por Aluno (ProUCA), was launched in 2008, with the same formula but a different laptop, produced by Intel and Metasys. This computer, named Classmate, still used open software but with an operational system that replicated the Windows structure and a work area with folders. It looked like a miniature of a usual notebook, with darker colors than XO and a hard keyboard.
In 2012, we carried out one-year ethnographic research at four Brazilian public schools - two located in the States of Bahia (Northeast region) and two in Santa Catarina (Southern region) - adopting the same research methodology applied in Italy. It is relevant for our analysis to notice that two researched schools had XO laptops from the initial OLPC program and two already had the newer Classmate model.

Research method

The nature of our study was exploratory. We considered the classroom ecosystem as our analytic unit. Two research questions guided the study:

- How might teacher's choices support learning emergence?
- How might material artifacts (laptops) influence interactions in the ecosystem?

The approach of the research was ethnographic, with the use of different tools. In each country, we conducted semi-structured, in-depth interviews with 10 school teachers; participant observation in 10 classrooms for one whole school year; and focus groups with pupils in each classroom. Interviews were transcribed, coded and categorized through the method of the Grounded Theory (Glaser & Strauss, 1967). Data analysis was carried out through categories arising from the theoretical encounter between Complexity theory and Media Ecology, which contributed by showing communication processes and emerging patterns of technology-mediated teaching practices.

Results

Italian and Brazilian teachers used different strategies to manage the classroom complexity when faced with the OLPC/ProUCA laptop, respectively. These strategies always involved complexity reduction actions, such as incorporating the new technology within established educational practices, guiding pupils through educational activities with the use of the laptop and constantly seeking feedback. In the classrooms, we observed the occurrence of both kinds of feedback - positive and negative - being offered to pupils. Due to the limited space available here to discuss our results, below we will present two vignettes with situations observed in each context, complemented by excerpts from interviews and focus groups.

Italy - immigrants' social inclusion

To the question "Did you notice any changes in pupils' skills after they started using the laptop?", most of the interviewed Italian teachers replied that they did not notice any difference, sometimes justifying this answer with lack of time to see effects, as it was the first year of OLPC implementation. They acknowledged that pupils had developed some technical skills, as well as increased problem-solving abilities. Two answers drew our attention especially, as teachers mentioned some processes of autonomy creation and information processing, but one of them was especially interesting for the scope of our analysis. The teacher of a 4th grade class told us a story about a group of children who were marginalized in her class, because of their different cultural background and aesthetics. They were second-generation immigrants from India and because of their religion, Sikhism, the boys had long hair wrapped in small, white turbans. They would mainly stay together, as a silent barrier divided them from the rest of the class. One day, the teacher saw a video that one of them had taken at home, during a religious celebration with his family, and had edited with the XO laptop. She asked if he wished to share it with the rest of the class, and the boy, at first very shy, accepted. This was a turning point for him, she said. The other classmates became curious about how to edit a film, add titles and other features, and while they were asking about technical issues they started to actually get interested in the content itself. They wanted to know about the religious party, and they had questions about the special clothes that the boy's relatives were wearing, about their hairstyle and about food. The other Sikh boy in the class also got involved in the dialogue, and the two excluded boys became protagonists for a moment.

> I would have never expected these two children of my class to have such good results in this project. I mean, we're talking about children who've always had the role of "followers". 'Because it was always someone else who was the leader, who knew better how to communicate, and so on. But now, for instance, you could say that one of them has become a real leader: he goes everywhere, he knows a lot, and he leads the group! (4th grade teacher).

At the school, there were children from many different cultures, as often happens in many cities in Northern Italy. In a 5th grade class, one observed situation gave us another example of marginalization. The teacher had given children some time to use the chat application freely. The only rule was to choose a friend in advance, and then write to him/her. The teacher's goal in this activity was to train writing and spelling in Italian. However, two foreign children were not chosen as friends, perhaps because of their limited skills in writing. As such, they were forced to communicate with each other, which made communication difficult.

During our time of data collection at this school, we witnessed a turning point in this class. The teacher from 4th grade told her colleague what had happened in her class with the two Indian boys and their amateur film about a traditional celebration. The colleague liked the idea and decided to replicate it in the 5th grade class. She encouraged pupils to take a picture with a relative and tell a story about them. The result was very positive, and immigrant children provided an interesting photographic composition and aesthetic choices.
In some cases, answers that pupils gave during focus groups also had a relationship with their previous experiences, in their country of origin. It was evident that the children were very keen to share their memories with the researcher. Some examples follow:

> Girl: I pulled up this game we have on the laptop; it's called Gcompris, and I chose maths...there are many numbers to move, it's beautiful. In my country, they always sell that game, people like it very much.
> Researcher: where are you from?
> Girl: Ukraine. Tomorrow I can bring it if you want, I'll show it to you. (Focus group 3rd grade)

> Boy: I like to write and look up things [information]. Once I went to Peru and I wrote as if looking for animals, I searched for an animal...I put: "carnivorous", which is an animal that eats meat, but I didn't found it.
> Researcher: but when was that?
> Boy: I was born in Peru! And you give them 50 centavos, cents... and you go to the Internet and I searched for *este* [sic]...animals. (Focus group 4th grade)

These spontaneous conversations confirmed that socially excluded students benefit greatly from adults' recognition about their abilities to use the laptop.

Brazil - self-discipline through responsibility

When asked "Did you notice any changes in pupils' skills after they started using the laptop?", most of the Brazilian teachers answered negatively. They explicitly mentioned learning, or lack thereof, saying that they could not see improved outcomes from the use of the laptop. The only changes they could see were ones of a technical nature.

> Learning...can we consider it learning? Learning how to have fun, looking for sources of leisure...well, I think that is also learning. They made some progress in that. But, as to learning let's say *content*, no! (5th grade teacher).

> Of course, they learn, and I learn together with them…[...] But I think it's necessary to face the issue of their behavior, their lack of discipline and interest (5th grade teacher).

What was evident from participant observation was teachers' struggle to keep the class silent and focused. Most of those interviewed complained about pupils' lack of discipline and interest, which according to their view, was compromising their learning outcomes. However, in the observations we also noticed that whenever the pupils were given responsibilities and/or asked for ideas to support the teacher, a spark of interest was lit and the mood of the class changed. One teacher related positive results to her own openness towards the unexpected turns that a lesson with the laptop could take.

> We often go through an activity, and when we plan we believe that that activity will have an expected result. But at the moment of the child's interaction with the laptop, the plan is *transcended*, and the results are often different from those we predicted. I find this interesting because we see children's productivity in the results they bring. Many times, we couldn't even imagine it going that way. They even give suggestions! We think about making, for example, a list of words and suddenly when they open the application, another idea comes up: "teacher, how about we do it this way, instead? [...] These insights refresh our practice, when we think that we've tried everything already in our teaching" (3rd grade teacher).

At this teacher's school, a student mentoring project had been implemented by the principal. The school had two shifts, with children attending either in the morning or in the afternoon. A group of volunteer pupils would stay at school once a week for one extra shift, and help teachers with the use of laptops in other classes. The mentors would prepare the laptops, and keep walking by the desks during the lesson, helping students with technical and educational advice to carry out the activities.

> Girl 1: We learn many things with the laptop, and we can talk to our teachers too. I like it. And I like teaching other students who don't know how to use it. Sometimes it's difficult to explain it to them, especially the youngest ones. But then you can see how they evolve!
> Researcher: What about you?
> Girl 2: I like helping students to learn; what I *don't* like is seeing students breaking the laptop.
> Researcher: Oh, and why do they break it?
> Girl 2: It's because they don't know how to handle it properly, they touch everywhere, they leave a lot of folders open! And some are proud, they say they know everything and don't need help... (Focus group, 5th grade)

The school had even presented the mentoring project at a local meeting with other schools earlier that year. The 3rd grade teacher recalled:

> Listening to our boys, I was thrilled because - My! - it is very cool when you see a child, with his independence, take a microphone and speak. And their speech went more or less like this: "at my school there is UCA, and it's important to me, because through UCA I learned to play, edit text, play the ABC game". And he went on reporting his experience and the impact that it had on his life. It is not prepared at all, you see the nervousness of children who were unable to speak, at the beginning. And you see in the speech what each one liked most...there was one who said: "I'm a mentor. UCA is important to me because when I go to the little boys' class, they call me aunt".

Pupils who volunteered as mentors had the feeling they were giving actual support to teachers during class, and every year there was a long waiting list for those who wished to become mentors.

Discussion and conclusion

As part of an ecological analysis, we can find in both the above-presented vignettes communicative choices that have made change and emergence possible in the observed classroom ecosystem.

The first situation involves an initial “accident” - a teacher spots a homemade video of a family celebration on a pupil’s laptop. The accident is followed by a “choice” - the teacher values what she sees and asks the pupil to share his knowledge about editing a video with the class. The teacher’s choice is expressed in the form of “feedback” to the pupil, positive feedback that increases complexity - a new situation of exposure for a shy and marginalized 9 year old - and unbalance in the class in which he is not accepted. What follows is unexpected: classmates not only show interest in the video but also in the story that it tells. In McLuhan’s terms, we could reflect here about the loose distinction between ground and figure, between environment and content. The hardware that make it possible to display the video is not only the platform supporting it, but rather the very reason why an immigrant child - who never had a laptop before - recorded a video. This example shows us how the content of a medium is always another medium (McLuhan, 1964). In addition, if we consider that all media are extensions of human faculties (McLuhan & Fiore, 1967), the pupil’s video represented an extension of his memory, a moment whose images he recorded and edited to keep alive when at school, an extension of happiness and joy. The teacher’s request to share the video pierced into this intimate space, to extend the memory of that moment to others, and by so doing, gave it a different meaning, in the encounter with other cultural backgrounds.

In Bateson’s terms, the teacher and the boy are leading with uncertainty, and they see learning emerging from this situation, which consists in peers’ communicative exchange at two levels, about the laptop’s features, but also about Sikh religious rituals. The knowledge acquired at this moment by pupils through interactions between them and with the environment feeds back into the system by creating new meaning. The emergence of new relationships in the classroom, which also implies a change in roles (from being “followers”, the immigrant children became “leaders”), engenders a different scale of change - one in the school system. In fact, another teacher became interested in marginalized pupils’ social integration through the use of the laptop and another classroom ecosystem was contaminated by change, resulting in emerging reconfigurations.

The second situation tells us about stagnation, tiredness and lack of motivation both from teachers and pupils. Interestingly enough, these aspects were much more evident in the two schools were the Classmate laptop model had been implemented. Perhaps, the desktop design of the hardware or its content organization in folders gave children the idea of “work” more than “fun” with the computer, with the result of not wanting to collaborate with teachers by doing the activities asked of them. It might be also that the software itself was not appealing, and the content became unappealing too, in a sort of sensorial overlap of feelings. In McLuhan’s terms, the inseparability of ground and the figure would have certainly given this explanation.

In three out of four schools, teachers had already given up on the ProUCA program, at the moment of our observation. They were aware that they should accept the disruptive presence of the laptop, but they did not know how to deal with the nonlinearity that this new element caused in the ecosystem, and wished more control and discipline. From our understanding, teachers who mostly complained about the changes that had occurred with the ProUCA did not consider *themselves* as part of the changing ecosystem. They were using the laptop as an instrument, to support their existing teaching practice and established relationships (Pischetola & Miranda, 2019). Therefore, a general lack of rules worked as positive feedback loops for the ecosystem classroom, and led to unproductive chaos, followed by both teachers’ and pupils’ inability to deal with uncertainty. Our analysis was possible in relation to the fourth school, which actually represented an exception. Here,

teachers and principals were willing to “take the risk” by being open to disruption, nonlinearity and disorder. They would encourage the increase in complexity, by constantly accepting pupils’ feedback and experimenting trial-and-error processes, which correspond to Bateson’s II level of learning. Children were allowed to propose new ideas for their lessons with the use of the laptop (positive feedback), but they also worked as mentors to support teachers (complexity reduction). There was mutual interaction between all agents taking part in the school system including principals, and both pupils and teachers were learning from what emerged.

What we can further learn from Media Ecology and Complexity theory is that communicative choices have crucial importance in terms of keeping the ecosystem open and alive, or cutting off its connections through negative feedback to reduce complexity when necessary. In the educational field, choices can also lead to emerging teaching practices and/or can give new meanings to sensorial experiences and existing relationships. When we think of school in this way, we can imagine self-renewing dynamics, creativity and new motivation.

References

Alhadeff-Jones, M. (2008). Three Generations of Complexity Theories: Nuances and ambiguities. Educational Philosophy and Theory, 40(1), 66–82. DOI: https://doi.org/10.1111/j.1469-5812.2007.00411.x

Apple, M. W. (2004). Creating Difference: Neo-Liberalism, Neo-Conservatism and the Politics of Educational Reform. Educational Policy, 18(1), 12–44. DOI: https://doi.org/10.1177/0895904803260022

Bachelard, G. (1934/2003) Le Nouvel Esprit Scientifique. Paris: Presses Universitaires de France.

Barab, S., & Roth, W. M. (2006). Curriculum-Based Ecosystems: Supporting Knowing From an Ecological Perspective. Educational Researcher, 35(5), 3–13.

Barron, B. (2006). Interest and Self-Sustained Learning as Catalysts of Development: A Learning Ecology Perspective. Human Development, 49(4),193–224. DOI: https://doi.org/10.1159/000094368

Bateson, G. (1972). Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology, New York: Bantam Books.

Bateson, G. (1986). Mente e Natureza: uma unidade necessária. Rio de Janeiro: Francisco Alves Editora.

Bateson, G. Bateson, M.C. (1994). El temor de los angeles. Barcelona: Gedisa Editorial.

Berthoz, A. (2009). La Simplexité. Paris: Odile Jacob.

Biesta, G. & Osberg, D. (2010). Complexity, Education and Politics from the Inside-Out and the Outside-In. In: Osberg, D. & Biesta, G. (eds.). Complexity Theory and the Politics of Education. Rotterdam: Sense Publishers. DOI: https://doi.org/10.1163/9789460912405_002

Capra, F. (1996). The Web of Life: A New Scientific Understanding of Living Systems. New York: Anchor Books.

Charlton, N. G. (2008). Understanding Gregory Bateson. Mind, Beauty and the Secret Earth. Albany, State University of New York Press.

Cilliers, P. (2001). Boundaries, Hierarchies and Networks in Complex Systems. International Journal of Innovation Management, 5(2), 135–147.

Davis, B. & Sumara, D. (2008). Complexity as a theory of education. Curriculum Inquiry, 5(2), 33–44.

Fenwick, T. (2009). Responsibility, complexity science and education: Dilemmas and uncertain responses. Studies in Philosophy and Education, 28(2), 101-118.

Fenwick, T. Edwards, R. & Sawchuk, P. (2011). Emerging Approaches to Educational Research. Tracing the sociomaterial. London: Routledge.

Freire, P. (1996). Pedagogia da autonomia: saberes necessários à prática educativa. São Paulo: Paz e Terra.

Fuchsberger, V., Murer, M., Tscheligi , M. (2013). Materials, Materiality, and Media. Proceedings of the CHI 2013: Changing Perspectives, Paris, France.

Gee, J. P. (2007), What Video Games Have to Teach Us About Learning and Literacy. London: St. Martin's Publishing Group.

Gee, J. P. Learning and Games. (2008). In: Salen, K. The Ecology of Games: Connecting Youth, Games, and Learning. The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning. Cambridge, MA: The MIT Press. 21–40. DOI: https://doi.org/10.1162/dmal.9780262693646.021

Glaser, B. & Strauss, A. (1967). The Discovery of Grounded Theory: Strategies for Qualitative Research. Chicago: Aldine Pub.

Gorur, R., Hamilton, M., Lundahl, C. & Sjödin, E. S. (2019) Politics by other means? STS and research in education, Discourse: Studies in the Cultural Politics of Education, 40(1), 1–15, DOI: https://doi.org/10.1080/01596306.2018.1549700

Hecht, M., & Crowley, K. (2019). Unpacking the Learning Ecosystems Framework: Lessons from the Adaptive Management of Biological Ecosystems. Journal of the Learning Sciences. DOI: https://doi.org/10.1080/10508406.2019.1693381

Heinsfeld, B. D.; Pischetola, M. (2019). Discourse on technologies in public policies on education. Educação & Pesquisa, 45. DOI: https://doi.org/10.1590/s1678-4634201945205167

Helmreich, S. (2004) The Word for World is Computer: Simulating second natures in artificial life, in: M. N. Wise (ed.) Growing Explanations. Historical perspectives on recent science. London: Duke University Press, 275–300.

Howard, S. & Gigliotti, A. (2015). Having a go: Looking at teachers' experience of risk-taking in technology integration. Educ Inf Technol (2016), 21, 1351–1366. DOI: https://doi.org/10.1007/s10639-015-9386-4

Hu, J., Huhmann, B. A., Hyman, M. R. (2007). The Relationship between task complexity and information search: The role of self-efficacy. Psychology & Marketing, 24(3), 253–270. DOI: https://doi.org/10.1002/mar.20160

Jenkins et al. (2006). Confronting the Challenges of Participatory Culture: Media Education for the21stCentury. MacArthur Foundation Report on Digital Media and Learning.

Katz, I. & Assor, A. (2006). When Choice Motivates and When It Does Not. Educational Psychology Review 19(4), 429–442. DOI: https://doi.org/10.1007/s10648-006-9027-y

Ito, Mizuko et al. (2008). Foreword. In: Salen, K. The Ecology of Games: Connecting Youth, Games, and Learning. The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning. Cambridge, MA: The MIT Press. vii–ix. DOI: https://doi.org/10.1162/dmal.9780262693646.vii

Le Fevre, D. (2014). Barriers to implementing pedagogical change: The role of teachers' perceptions of risk. Teaching and Teacher Education, 38(6), 56–64. DOI: https://doi.org/10.1016/j.tate.2013.11.007

Le Moigne, J.-L. (1996) Complexité, in: D. Lecourt (ed.), Dictionnaire d'Histoire et Philosophie des Sciences. Paris: Presses Universitaires de France.

Le Moigne, J.-L. (2003) Le Constructivisme. Modéliser pour comprendre (vol. 3). Paris: L'Harmattan.

Lenz Taguchi, H. (2019). Going Beyond the Theory/Practice Divide in Early Childhood Education. London: Routledge.

Logan, R. K. (2007). The biological foundation of media ecology. Explorations in Media Ecology, 6(1), 19-34.

Logan, R. K. (2010). The biological foundation of media ecology. Explorations in Media Ecology, 9(3), 141–156.

Logan, R. K. (2011). Figure/Ground: Cracking the McLuhan Code. E-Compós, Brasília, 14(3), Sep/Dec.

Mason, M. (2008). Complexity Theory and the Philosophy of Education. Educational Philosophy and Theory, 40(1), 4–18.

McCarthy J. (1989) Artificial Intelligence, Logic and Formalizing Common Sense. In: Thomason R.H. (ed). Philosophical Logic and Artificial Intelligence. Dordrecht: Springer.

McLuhan, M. (1964). Understanding media. New York, NY: McGraw Hill.

McLuhan, M. (1969). Playboy Magazine Interview. Playboy Magazine, March.

McLuhan, M.; Fiore, Q. (1967). The Medium is the Massage. New York: Bantam Books.

McLuhan, M., McLuhan, E., & Zingrone, F. (1995). The essential McLuhan. New York, NY: Basic Books.

Molinaro, M.; McLuhan, C.; & Toye, W. (Ed.) (1987). Letters of Marshall McLuhan. Toronto: Oxford University Press.

Morin, E. (1980) La Méthode (vol. 2) La vie de la vie. Paris: Seuil.

Morin, E. (1991) La Méthode (vol. 4) Les idées. Leur habitat, leur vie, leurs moeurs, leur organization. Paris: Seuil.

Morowitz, H. J. (2002). The Emergence of Everything: How the World Became Complex. Oxford: University Press.

Muthitachareon, A., Barut, M. & Saeed, K. A. (2014). The Role of Uncertainty Stemming from Product Monetary Value in Online Auctions: The Case of Search Goods. International Journal of Electronic Commerce, 19(1), 65–98, DOI: https://doi.org/10.2753/JEC1086-4415190102

Oliver, M. (2011). Technological determinism in educational technology research: Some alternative ways of thinking about the relationship between learning and technology: Educational technology and determinism. Journal of Computer Assisted Learning, 27(5), 373–384. DOI: https://doi.org/10.1111/j.1365-2729.2011.00406.x

Osberg, D., & Biesta, G. (2010). The end/s of education: Complexity and the conundrum of the inclusive educational curriculum. International Journal of Inclusive Education 14(6), 593–607. DOI: https://doi.org/10.1080/13603110802530684

Osberg, D., Biesta, G., & Cilliers, P. (2008). From Representation to Emergence: Complexity's Challenge to the Epistemology of Schooling. Educational Philosophy and Theory, 40(1), 213–227. DOI: https://doi.org/10.1111/j.1469-5812.2007.00407.x

Osberg, D. & Biesta, G. (2020). Beyond curriculum: Groundwork for a non-instrumental theory of education, Educational Philosophy and Theory, DOI: https://doi.org/10.1080/00131857.2020.1750362

Pischetola, M. (2011). Educazione e divario digitale. Idee per il capacity building. Milano: Unicopli.

Pischetola, M. (2019). Teachers and Technologies in Brazilian Schools: a Study from the Perspective of Media Ecology. Italian Journal of Sociology of Education, 11(2), 411–427. DOI: https://doi.org/10.14658/pupj-ijse-2019-2-20

Pischetola, M. & Miranda, L. V. T. (2019). A sala de aula como ecossistema. Tecnologias, complexidade e novos olhares para a educação. Rio de Janeiro: Editora PUC-Rio.

Prigogine, I. (1969). Structure, Dissipation and Life. Theoretical Physics and Biology, Versailles, 1967. Amsterdam: North-Holland Publ. Company.

Ruesch, J., & Bateson, G. (1951). Communication, the social matrix of psychiatry. New York: W. W. Norton & Company.

Salen, K. (2008). The Ecology of Games: Connecting Youth, Games, and Learning. The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning. Cambridge, MA: The MIT Press. 1–20. DOI: https://doi.org/10.1162/dmal.9780262693646.021

Serenelli, F. & Mangiatordi, A. (2010). The 'One Laptop Per Child' XO laptop as a PLE. A cognitive artifact beyond hardware and software. Proceedings from The Personal Learning Environments Conference, Cornellá/Barcelona, July.

Sonsino, D., Benzion, U. & Mador, G. (2002). The Complexity Effects On Choice With Uncertainty – Experimental Evidence. The Economic Journal, 112:482, 936–965. DOI: https://doi.org/10.1111/1468-0297.00073

Strate, L. (2013). Gregory Bateson and Paul Watzlawick: From the ecology of mind to the pragmatics of media ecology. Explorations in Media Ecology, 12(3-4), 199–207(9). DOI: https://doi.org/10.1386/eme.12.3-4.199_1

Von Bertalanffy, L. (1950). An outline of general system theory. British Journal for the Philosophy of Science, 1, 134-165.

Weaver-Hightower, M. (2008). An Ecology Metaphor for Educational Policy Analysis: A Call to Complexity. Educational Researcher, 37(3), 153–167 DOI: https://doi.org/10.3102/0013189X08318050

Winkin, Y. (1981). La nouvelle communication. Paris: Éditions du Seuil.