DC(S)
DESIGN CULTURE(S) | CUMULUS ROMA 2021
JUNE 08.09.10.11, SAPIENZA UNIVERSITY OF ROME

Art, Design, and Mathematics: Software programming as artifice in the creative process

Carlos de Oliveira Junior[a], **Eduardo Ariel de Souza Teixeira**[b]
[a]ESPM
[b]ESPM
*quissama@gmail.com, eariel@espm.br

Abstract | This article seeks to address the creative qualities of programming in an artistic context. When questioning the limitations of graphical interfaces, we can reflect on the contribution of Programming as a resource to go deeper into a creative process in the context of digital media, robotics, interactivity, generativity and other possibilities. A exploratory research study was conducted through interviews with laboratory coordinators from educational institutions in Rio de Janeiro, who have been exploring the possibilities between Art and Technology for at least a decade. Among the main findings that mark the creative process are experimentation and multidisciplinarity. Distaste for Mathematics appears as the main barrier to the insertion of Programming in an artistic context.

KEYWORDS | MEDIA ART, DIGITAL ART, DESIGN, ART, PROGRAMMING

1. Introduction

1.1 Creative Coding: Art and Technique

A fundamental part in the transformation of an increasingly technological society (Figure 1), Programming allows describing and executing tasks on computers, its use is widespread for functional and deterministic purposes.

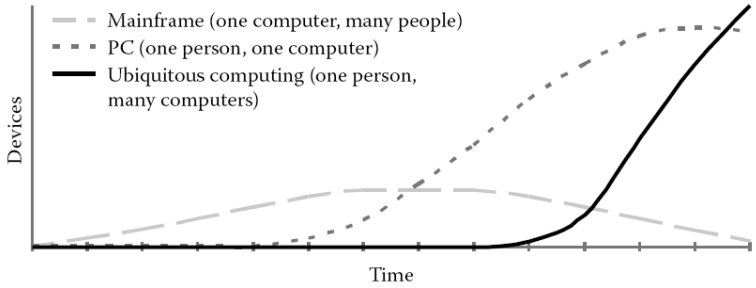

Figure 1. The three modern computing eras (source: Krumm, 2010) illustrates how computers are becoming smaller and more present in our lives.

The use of Programming in an artistic context proposes another purpose. Creative Coding "is not a tool; it is a new way of expressing yourself." (Maeda, 2004, p. 113), in the work that possibly coined the term, in the book "Creative Code". By placing artistic expression at the center of Creative Coding, Maeda distinguishes it from traditional programming.

By writing codes, enabling the creation of one's own tools, it is possible to expand and democratize the design practice, "Conferring (re)designability to technology expands Design. It brings forth a culture that is increasingly understood as co-constitutive and driven by design practice" (Krippendorff, 2000, p.90).

Since the late 1960s, artists and scientists have sought to break the creative limits that emerged with the arrival of computers. According to Oakim (2018), the first visual experiments were generated through a computer by mathematician Frieder Nake, arousing curiosity in the artistic and academic community.

The exploratory proposal of this article analyzes how Programming fits into the creative process and what challenges are encountered in the learning process. Four researchers were interviewed in search of the creative qualities found in the dichotomy between art and technology, concepts that were not always distant from each other:

> "We know, for example, that the Greek word *téchne*, from which technology derives, refers to any and all productive practices and even included artistic production. The Greeks made no distinctions of principle between art and technique, and this assumption went through much of the history of Western culture, until at least the Renaissance (Dufrenne, 1980, p. 165). For a man like Leonardo da Vinci, painting a canvas, studying human anatomy or Euclidean geometry and designing the technical scheme of a machine constituted a single intellectual activity" (Machado, 2001, p.24)

1.2 Interfaces and hidden codes

With the popularization of graphical interfaces in the 1980s, artists moved away from coding, but with the emergence of open-source culture, the community created its own tools that facilitate the learning of coding in an artistic context, such as Processing[1], enabling creative coders to go beyond the limitations of closed source software and its interfaces.

When observing the transformations caused by computers in the practice of Design, Kripperndorff (2000) analyzes the emergence of these graphical interfaces:

> "Personal computers led to the following paradigm: interfaces. Similarities to languages, interactivity, internalized experiences and the possibility of self-teaching made the interfaces not explainable in psychological, ergonomic and semiotic terms, making the language of functionalism, consumer preferences and aesthetic appeals obsolete. Interfaces are processes, they decomposed the artifacts into interactive sequences." (Krippendorff, 2000, p.89)

The techniques used in Creative Coding require different levels of knowledge, when relating to Programming, each problem becomes a possibility to broaden the understanding of how the software (read Black Box) works. Flusser (2011) analyzes the Black Box phenomenon in the context of the camera, here it can be understood as any element whose functioning is obscure, as such the interfaces:

> "Once acquired, the camera will turn out to be a curious toy. Although it rests on complex scientific theories and sophisticated techniques, it is very easy to manipulate. The device proposes a structurally complex game, but functionally simple. A game that is the opposite to chess, which is structurally simple, but functionally complex: it is easy to learn its rules, but difficult to play well. Anyone who has the "latest model" camera can shoot "well" without knowing what is going on inside the camera. Black box." (Flusser, 2011, p.78)

Being in front of an image editing software distributed by the major software manufacturers, despite allowing a varied range of results, does not contribute to the understanding of how the technique used in the software can be remodeled to enable a new creative bias, these software solutions are made available "closed", the codes are not accessible, protected by the interests of intellectual property.

The work of Gilbert Simondon was also considered, a French philosopher who developed a system of thinking about invention and technical objects. Simondon "does not only aim at the technical dimension of human life, it defines life within the technical dimension" (Camelozi, 2015, p. 446). If we connect the technological obscurity denounced by Flusser

[1] Processing, ambient for Creative Coders, created in 2001. Retrieved January 23, 2020, from https://processing.org/

and his ability to question the automation of consumption of these devices (interfaces), we find in Simondon's work a way to decompose technical objects into layers:

1. External layer: appearance, how the object manifests itself socially.
2. Intermediate layer: utilization, compatibility between the object, the medium and the operator.
3. Internal layer: functional core, intrinsic compatibility that the object is capable of producing, making natural resources (energy) compatible with the objective.

Therefore, when questioning closed source tools and their interfaces, we can reflect on the contribution of Programming as a resource to go deeper into the creative process, in the context of digital media, robotics, interactivity, generativity and other possibilities.

2. Method

An exploratory research was conducted through interviews with laboratory coordinators from educational institutions in Rio de Janeiro, who have been exploring the possibilities between Art and Technology for at least a decade. The interviews were conducted through a semi-structured script containing 17 questions, oral recording procedures were adopted and later transcribed. Discourse analysis (Vergara, 2010) was used to present the different views of the interviewees.

The four interviewees (Table 1) authorized their nominations, they can be classified as qualified informants according to their academic trajectory, representativeness in the national and international scene, and historical contribution in Art and Technology. The beginning of Computer Graphics and Digital Art in Brazil is intertwined with the heterogeneous trajectory of these researchers.

Table 1. Interviewees organized by order of interview.

Name	Academic Title	Laboratory
João Bonelli	PhD in Design at the Pontifical Catholic University of Rio de Janeiro	LIFE: Laboratory of Physical and Experimental Interfaces
Carlos Nóbrega	Postdoc in Art and Technology at the University of Brasilia	NANO: Nucleus of Art and New Organisms
Rejane Spitz	Postdoc in Electronic Art at the University of California	LAE: Laboratory of Electronic Art
Luiz Velho	PhD in Computer Science from the University of Toronto	VISGRAF: Vision and Graphic Laboratory

The first three interviewees went through the entire script, offered valuable contributions and indicated the way to investigate Mathematics as a challenge for inserting Programming into the artistic context, an aspect discussed more specifically with the fourth interviewee, Luiz Velho.

3. Interviews

3.1 About the Interviewees

The interviewees' academic trajectories were represented by a timeline (Figure 2) built from the facts highlighted in the interviews and the academic milestones listed in Lattes Platform (Virtual Resume System).

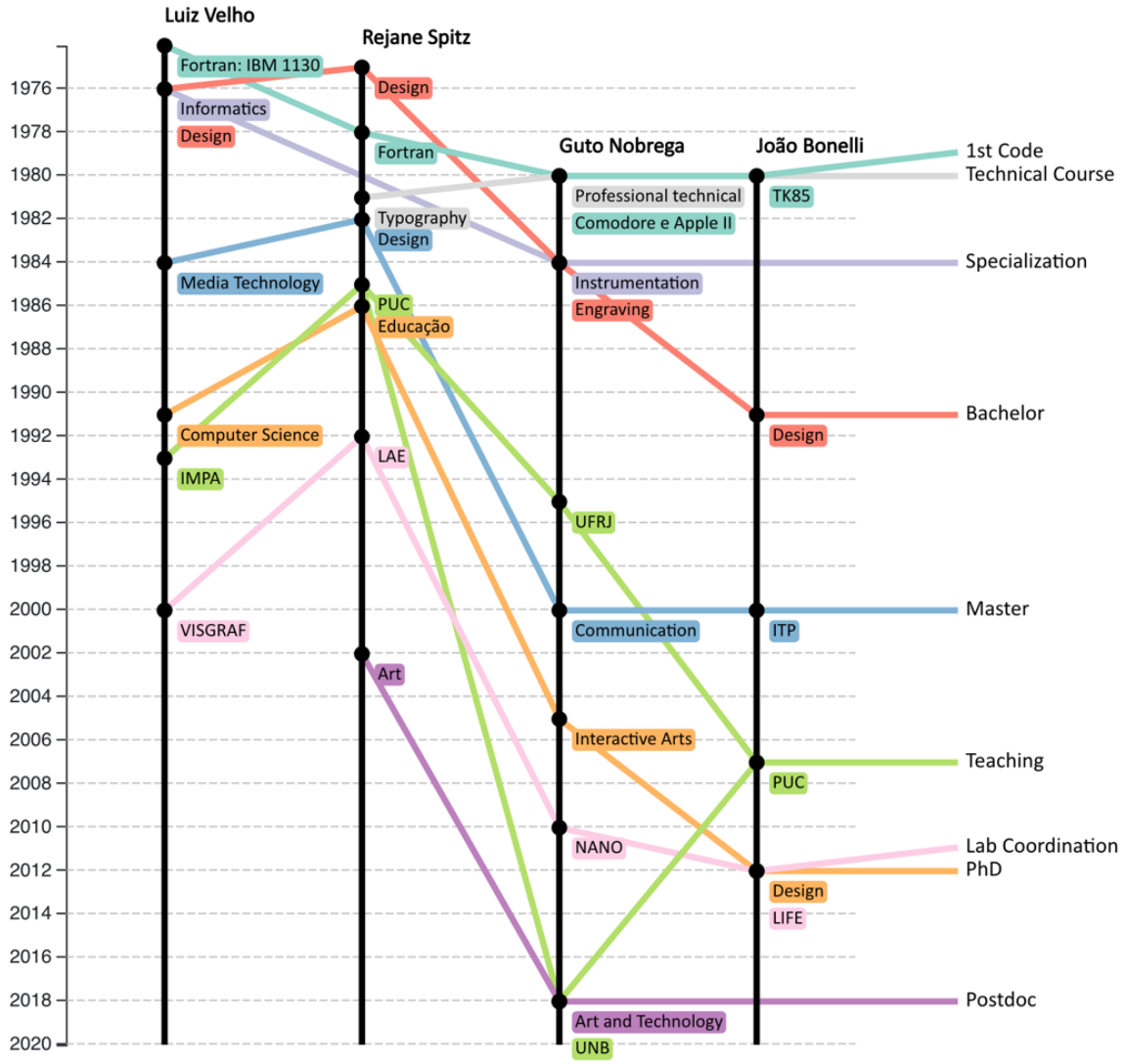

Figure 2. Timeline of the interviewees' academic trajectory. Each respondent is represented by the vertical line, points highlight the milestones of their trajectories. The landmarks were grouped by lines that cross the chart on the horizontal axis, identified on the right side of the chart.

Respondents were asked "when was your first contact with Programming?". The answers varied between childhood and the beginning of graduation, where two of the interviewees reported handling punched cards with Fortran language.

3.2 Creative process

The following question was asked: "how do you observe the creative process?". For Spitz (2019), creativity is related to the need for survival, “actions that are caused by curiosity”:

> “Creative processes are the result of an individual effort caused by curiosity. Anything is a creative process, as long as someone is looking to know, create or build. I think the creative process is being given a lot of value, it is being highly valued. (...) Creativity is caused by the need for survival. You have to be creative to survive, regardless of anything. Survival depends on curiosity that leads to creative processes. We are creative in absolutely everything, in the way of reproducing, feeding, dreaming, swimming and all these were human creations for survival.” (Spitz, 2019)

Bonelli (2019) observes the creative process through experimentation:

> “It is the process of doing something, reflecting on what you did, evaluating, and then doing something else based on these reflections, evaluating and doing something and something else (...) It is not planning and having something in the end, as if in the first day of the project you knew exactly where you were going to go, but doing several experiments and seeing your work evolve after each experiment, until you reach the final result. Constantly re-evaluating your results and objectives. We propose seeing the Design process not as a straight line from A to B, but as a spiral, circular shape, where you arrive at the center, which is your goal, through development and experimentation.” (Bonelli, 2019)

Drawing is in the base of Nóbrega's creative process (2019):

> “Usually, people consider the best drawing the one that most effectively represents the thing being observed. The problem is: what is representation, what does it mean to represent something more effectively, because of visual similarity or because it brings information about that thing? You can have extremely simple, delicate drawings that differ from classic drawings, and that are extremely powerful in describing the sensations produced by the thing in question. Great masters, for example, sometimes take a line, a dash, and it takes us directly to their time, 500 years ago, 200 years ago, and you will feel as if you have been transported by that image. So, what is the potency of that image? The idea is to use drawing as a tool for discovering and modulating your own identity, at that moment and in that space.” (Nóbrega, 2019)

According to Nóbrega (2019), among the various aspects that imply the creative process, there is “awareness of an altered state” in a validated reality, one of the 3 realities defined by Ascott (2000). Nóbrega (2019) describes validated reality as:

> “Consensus reality, which has a number of issues that are consensual, i.e., it exists because there is a belief, like believing I am here talking to you, and if that belief fails, we stop talking. Reality is not something given a priori, if you start thinking about it, a very wide range of possibilities opens up. So for me, this is the matter in the creative process. The difficulty in creativity is just when you limit the speculative and exploratory aspect of the situation. Of course you master certain aspects, it is important, you will not be making contributions in areas you are not deeply experienced. Within this limit, you try to expand as much as possible with variables, which can bring some freshness to that.” (Nóbrega, 2019)

3.3 Programming and creative process

Then the following questions asked "How do interviewees see the role of Programming in the creative process?". Nóbrega (2019) analyzes Programming as Art by itself:

> “I believe programming is expanded when it occurs within a certain system; it is connected, and it connects the system with the whole. It becomes participatory, and several projection mechanisms start to act there, I imagine. You are programming, you are creating something that will be alive there. I think you can think of it as a process of invention. Gilbert Simondon says it is only possible to invent something because there is synergy between your mental state and the thing being created, that is, there is a coupling, a kind of resonance. When you think about it, you are there generating that object in a mental process, you test it and take a series of actions that promote the life of that object, even without it physically existing. So I think that this synergy, probably, should happen in programming because even with the little experience I have, what fascinates me the most is the ability to change a variable and have an extremely complex modification in the work. (...) This is inherent to Art, to the creative process, and it is important that in programming it can be incorporated to a certain extent. I think it’s like the ace in the hole, how you handle the stiffness of programming so it opens up and brings life to the system.” (Nóbrega, 2019)

From another perspective, Bonelli (2019) sees Programming as a tool capable of creating other tools:

> “It is like a pencil, a hammer or a handsaw. It is something that will help you get a result, reach a certain result, that will empower you. It is a very powerful tool, because you can build a million things with programming, including a handsaw or hammer, or you can program a robot to saw wood.” (Bonelli, 2019)

Spitz (2019) sees Programming as knowledge, a resource that, like any other piece of knowledge, is part of the creative process:

> “Any knowledge is a resource for survival. It's the only thing you carry, and knowledge cannot be shared, information can be shared, data, but knowledge is individual, is indivisible. Knowledge is contained in a given being, what he/she has learned from his/her experience, and from data and information.” (Spitz, 2019)

3.4 Teaching programming in the artistic context

Then, the interviewees were asked "How do you see programming teaching in an artistic context?". Bonelli (2019) points out the differences between teaching traditional programming and teaching programming in an artistic context:

> “We realized that in the IT department, teaching is much more based on questions of logic. They already start giving object-oriented programming right from the start. This needs a lot of abstraction from students, so that they can understand what is happening "right away". We adopt the Processing principle, a programming environment for designers, and we start teaching programming through drawings. When learning with Processing, you start by making an ellipse, a square, choosing the fill color, dealing with the coordinates on the screen. You write, you play, you do something, and not only get results very fast, you also work with a language that designers are very fluent with. Shapes and colors every designer understands.” (Bonelli, 2019)

Spitz (2019) notes that there is a willingness to join Design and Programming:

> “Teachers who work a little with programming will tell you that now the new designer has to know how to program and so on. It is not what is happening, we have very little notion of programming for someone to think that we will solve the programming problems of the world. It is a programming layer at the base of Design, it is what we are doing today, whether this is going to change or not is another question.” (Spitz, 2019)

Spitz (2019) mentions that in the 1980s there was a movement that believed it was not necessary to know how to program, after all, everything was moving towards becoming friendly, in terms of interfaces that allowed quick learning and fast results. This in fact happened, but she notes that programming is becoming more friendly as well. Spitz (2019) and Nóbrega (2019) consider the arrival of Arduino as a decisive element that promoted transformation in this sense. For Nóbrega (2019), Arduino allowed people “to leave programming focused on image and go to programming focused on physical things ”.

Nóbrega (2019) indicates that “there has been a very expressive growth, over the last few years, in terms of opening up to this universe of “hacks”, of a maker culture, that you can do things”. Access “spread via this open source culture”.

3.5 Challenge of teaching programming in the artistic context

When asked about "What are the challenges for teaching Programming in an artistic context?", Bonelli (2019) says:

> “The biggest challenge is hate for Mathematics. In our education system, students get to the university filled with rage at their teachers who tortured them. Those teachers lacked motivation, were not compensated properly, were not talented, taught Mathematics based on threats, on the blackboard. When we talk about sine and

> cosine, they ask to leave. The first thing we need to do is to deconstruct, because students reach 18 years old with their ideas shaped." (Bonelli, 2019)

Based on this reflection, there was a need to investigate the relationship between Mathematics, Programming and Art. For this, interview with Velho (2019) was carried out, where he explains the relationship between Mathematics and Programming: "The scientific basis of computing and programming is Mathematics, if you take Mathematics, this idea of algorithm, you take Newton's method, which is a classic in Mathematics, a program, an algorithm of how you are going to do something". And he points out the importance of multidisciplinary work:

> "It is not possible to work only with mathematicians or experts, it needs to be a complete multidisciplinary group. (...) Today, society is going back to the era of Renaissance, because after Renaissance, we started to have specialization, where each one mind their own business and that's it. But it wasn't like that before. It was a holistic thing. We are going back to the time of Leonardo Da Vinci, who did Art, Science, Engineering etc. The future will be like that, for that people need to change their attitudes. You can't build a multidisciplinary team with people who consider themselves traditional artists and don't want to understand how things are working." (Velho, 2019)

The importance of collaboration between disciplines is also mentioned by Spitz (2019) in the same question:

> "The only way to make things happen is to have subjects in which Informatics, Design and Art students work collaboratively. If universities were not so compartmentalized... We have some subjects given by computing professors, but it is not the same thing. A class has to have students from Informatics, Design and Arts working on collaborative projects, half-half, 50/50, not 49 and 51." (Spitz, 2019)

In this place of exchange, where subjects gets mixed and need to speak the same language, the need to understand the outlier, in this case, Mathematics, is evident. Velho (2019) talks about the contributions of Mathematics:

> "We are at a very special moment in humankind. Mathematics is the engine of innovation, and people still haven't realized that. With the internet and the evolution of media, the third industrial revolution is happening in our society, but it is not mechanical, it is intelligent, it is mathematical intelligence. The three most important things today: biomathematics, artificial intelligence and the media. And Mathematics is behind this." (Velho, 2019)

When reflecting on the challenges of learning and teaching Mathematics, Velho (2019) says:

> "Mathematics is very simple, it has two aspects: essence is the concept, and the operational aspect is the accounts. The accounts can be laborious and sometimes even complicated, but when you know the concept and you are going to do it, it is easy. It is very specialized. But the central idea of Mathematics is simple. (...) People are what makes the difference." (Velho, 2019)

4. Analysis

A curious finding, but yet inconclusive, is the early contact with programming shared by the interviewees. Even for those with higher artistic inclination, an early contact with computers and programming suggests a familiarization with the necessary techniques to dialogue with emerging technologies and, therefore, a distinguished nature during a professional, artistic and academic trajectory. Today, more and more schools are providing programming for children all over the world. These courses use tools such as Scratch[2] to teach programming logic through the creation of games, interactive stories or parametric drawings. Plans such as UNESCO's (2019) technology literacy help future generations acquire knowledge to dialogue with technological transformation in a non-passive way.

The perception of a creative process was associated with the practice of each one, whether through drawing, experimentation or multidisciplinarity. Collaboration between disciplines was recognized as a key element for innovation. Based on Simondon's ideas of invention (2008), Design, as any other discipline, goes as far as Design can go, by collaborating with other disciplines, as a result of an "amplifying dialectics", it produces "functional surplus-value" (*plus-value fonctionnelle*): This explains, therefore, why technical inventions have "superabundant functions" (*fonctions surabondantes*), because it gives an amplifying leap regarding the potential of separate objects.

Choosing between multidisciplinary training, where Programming teaching would be inserted in other courses, versus specialist training, encountered an equalizing proposal: the collaboration between courses mediated by projects, where students from different courses can share and develop their skills.

The main barrier for the insertion of Programming in an artistic context appears to be the hate for mathematics. The feeling that "students accumulate negative experiences in their learning path" (Bonelli, 2019) can be observed in the percentage of students with adequate learning in Mathematics, where there is a "considerable growth over the period of the initial years of elementary school and very low levels in the final years and high school, with stagnation/downward trend in recent years." (Todos Pela Educação, 2019, p. 24)

According to an evaluation carried out with 600,000 students from 79 countries, the challenge of stimulating the pleasant learning of Mathematics is a worldwide challenge:

> "76% of students attained Level 2 or higher in Mathematics. At a minimum, these students can interpret and recognize, without direct instructions, how a (simple) situation can be represented mathematically (e.g. comparing the total distance across two alternative routes, or converting prices into a different currency). However, in 24 countries and economies, more than 50% of students scored below this level of proficiency." (OECD, 2019, p. 15)

[2] Scratch, environment for teaching programming logic for children, created in 2015. Retrieved January 23, 2020, from https://scratch.mit.edu/

As seen in the interviews, the human element, i.e., teachers and students is yet, another decisive factor in teaching Mathematics. The Profissão Professor report (Todos pela Educação, 2018) carried out a quantitative survey of 2,160 basic education teachers from all over Brazil. Although the decisive factor for choosing a profession is the pleasure of teaching, half of the interviewed teachers answered that they would not indicate the profession to a young person, because of the "devaluation of the teacher, poor remuneration and difficulties in the routine" (Todos pela Educação, 2018, p. 15).

5. Final considerations

While graphical interfaces became more practical and more popular, so did Programming. Languages and tools were developed to facilitate learning and promote artistic expression through code.

Programming was observed as inserted in the creative process so that it solves the technical problems to make the project viable. It is marked by an experimental process, where unexpected discoveries are concatenated in the project.

The hate for Mathematics appears as a barrier to the insertion of Programming in an artistic context, where quantitative research in the Brazilian context has shown that the challenge extends itself to a precarious education system, and the main aspect of concern is the teacher. As a suggestion for other research, it might be interesting to investigate whether the same happens in other countries.

The 4 interviewees already had contact with Computers and Programming before or during the graduation in the areas of Art, Design and Mathematics, suggesting that they were more familiar and ready for the technological transformation along their learning path. It would be worth researching whether the teaching of Creative Code for young people collaborates with positive experiences in learning Mathematics.

References

Camelozi, M. (2015). Sobre o conceito de invenção em Gilbert Simondon [On the concept of invention in Gilbert Simondon]. 13th ed. São Paulo: Scientiae Zudia.

Dufrenne, M. (1980). Art and Technology: Alienation or Survival?. In: Woodward, K. M., *The Myth of Information: Technology and Postindustrial Culture*. Madison: Coda Press.

Flusser, V. (2011). Filosofia da caixa preta [Towards a Philosophy of Photography]. 1st ed. São Paulo: Hucitec.

Krippendorff, K. (2000). Design Centrado no ser humano: uma necessidade cultural [Human centered design: a cultural necessity]. Translation Gabrielle Meireles. Estudos em Design. Rio de Janeiro: Associação de Ensino de Design do Brasil (pp. 87-98).

Krumm, J. (2010). Ubiquitous Computing Fundamentals. New York: Taylor & Francis.

Machado, A. (2001). Máquina e Imaginário: O desafio das Poéticas Tecnológicas [Machine and Imaginary: the Challenge of the Technological Poetics]. 3rd ed. São Paulo: Edusp.
Maeda, J. (2004). Creative Code. High Holborn, London: Thames & Hudson.
Oakim, P. (2018). A Arte feita em código: um estudo de caso sobre a linguagem de programação Processing e sua utilização por artistas-programadores [The art made by code: a case study on Processing programming language and usage by artist-programmers] . São Paulo: Intermeios.
OECD (2019). PISA 2018 Results: Combined Executive Summaries, Paris: OECD Publishing. Retrieved January 23, 2020, from https://www.oecd.org/pisa/Combined_Executive_Summaries_PISA_2018.pdf
Simondon, G. (2008). Imagination et invention [Imagination and invention], 1965-1966. Paris: Les Éditions de la Transparence.
Todos pela educação. (2018). Educação Já: Uma proposta suprapartidária de estratégia para a Educação Básica brasileira e prioridades para o Governo Federal em 2019-2022 [Education Now: A supraparty strategy proposal for Brazilian Basic Education and priorities for the Federal Government in 2019-2022]. 3rd ed. 2018. Retrieved January 23, 2020, from https://www.todospelaeducacao.org.br/_uploads/_posts/170.pdf
Todos pela Educação. (2018). Profissão Professor [Teacher Profession]. Retrieved January 23, 2020, from https://www.todospelaeducacao.org.br/_uploads/_posts/23.pdf?750034822
Unesco. (2019). ICT competency standards for teachers: implementation guidelines. Version 1.0. Paris: UNESCO. Retrieved January 23, 2020, from https://unesdoc.unesco.org/ark:/48223/pf0000156209
Vergara, S. C. (2010). Métodos de Pesquisa em Administração [Methods of research in the field of administration]. 4th ed. São Paulo: Atlas S. A.

About the Authors:

Carlos de Oliveira Junior is a creative coder and Technology Director at SuperUber since 2011. He integrates content, hardware, software, design and architecture to develop unique projects. Graduated in Design and Master in Creative Economics at ESPM-Rio.

Eduardo Ariel de Souza Teixeira is a professor, researcher and academic director at ESPM. Graduated in Communication from ESPM, Post-graduated in Interface Design from Unicarioca, master and PhD in Design from the PUC-Rio. Post-Doctorate in Information Science from IBICT.