REDESIGNING THE PINHOLE CAMERA: AN EXERCISE ABOUT HOW TO DEVELOP AN "ECOBJET" FOR CREATING "BIOIMAGES"

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Abstract

This article falls within the Bioimages project, which in turn, stem from an educative and a technologic axis. The first axis presents itself like a perfect territory to debate the sustainability problems, promoting and questioning new pedagogical practices in Arts Education. The second axis focuses on innovative processes and technologies that drastically reduce the use of toxic agents that are usually present in the normal methods utilized in conventional photography labs. The design and construction of such innovative and accessible technologies using 3D printing will assist the biodegradable processes of film development because they are based on recycled and biodegradable plastics. In addition to that, their applications could be multiple. This axis is the origin of the “Ecobjects”: Various objects that have been designed and thought out on the basis of a sustainable ecologic circularity and which purpose is to help in the creation of bioimages. Analyzing the problem of plastic waste, the use and reutilization of Poly Lactic Acid (PLA) in 3D printing allows, in theory, a smaller ecologic footprint. This sustainable ecologic circularity recognizes the effort e3merged in the 50s driven by designers who protested the consumerist culture and the practice of “build-in-obsolescence”. During this investigation, it arose the need of redesigning the pinhole camera. The famous pinhole camera is still widely used by photographers and visual artists like Ruth Thorne-Thomsen. These small devices allow us to understand the basic light principles and the operation of light/image capturing devices. Its operation is so simple that the construction possibilities are infinite, and a wide variety of materials can be used. Relying on the principles of circularity and an action-research methodology, the pinhole camera was redesigned in a participatory manner with Teachers and Students of the Soares dos Reis Artistic School (EASR). By doing so, we managed to combine the digital and virtual aspects with the physical substances and the analogical processes, thereby creating a craft-lab environment. This collaborative approach propitiated a critical way of thinking based on real educational needs; therefore, it was possible not only to think about the function and shape of the object, but also about the system where this object is used. One of the needs was to explain the focal lengths using the pinhole camera. In response to this problem we designed normal and panoramic “backs”. These backs fit into two sliding mechanisms, both situated at different distances from the hole. The PLA material is translucent, but we surpassed this problem by choosing a black color and using three layers on the perimeter of the camera body with a 20% infill. Regarding the hole cover or the shutter system, the ideal choice is to print the piece(s) with a 100% infill. A complex image creation eco-system that relies on a circular logic of continuous reciprocity, gives us the chance to rethink old systems based on exclusionary and destructive logics. Perhaps the fact that this project is framed in the artistic education field will allows us to take a step back and spend time designing new image creation eco-systems and combine them with more recent technologies, like 3D printing. In this way we want to find new pedagogical practices and new worlds that enable us to reflect about the design of the future.

Keywords: Art Education, Sustainability, Ecology, Image, Photography, 3D Printing, Product Design.

1 INTRODUCTION

This article is framed within the Bioimages project and its primary focus is the design and development of one of the «Ecobjects»: a pinhole camera. The Bioimages project aims to develop new forms of sustainability regarding image creation, thereby providing new pedagogical practices in artistic education. One of the main goals of the project is to promote the use of an alternative and biodegradable chemistry for photographic development. On the basis of this ecological discussion, we designed an ecosystem of objects framed in a circular design that takes into account the type of materials used and their recycling capacity. We choose these options consciously considering the serious environmental problems humanity is facing, issues that are becoming more acute in the last decades.

Approximately six decades ago, more precisely in 1962, Rachel Carson, who was very aware of the damage that industrialisation and the global market were inflicting to the planet, said: «*The most alarming of all man's assaults upon the environment is the contamination of air, earth, rivers, and sea with dangerous and even lethal materials»* [1]. Since then, very little has been done in order to slow down an assault that continues today. Maybe because we are in the same era, the Capitalocene, with an apparent lack of political alternatives. In other words, in the same juncture. In this situation, the thief (mankind) continues with his assault following the proverb: «Opportunity makes the thief». We want to avoid the current cycle in which humanity turns into a kind of «Cornucopia City» [2] , where we buy and dispose products, in a never-ending vicious cycle. We seek other circularity, in a concious relationship with sustainability problems and whose practices are based on thinking and discussion and are not pseudo-solutions.

What is the scope of our action in front of the cataclysm started with the industrialisation? As teachers and researchers in Artistic Education we looked for materials in which these environmental concerns could intersect with artistic practices. During our research we came across the idea of rethinking the methods that are commonly used in analogue photography in high schools and higher education. These methods arise from the widespread wroth of photography carried out by well-known brands (Kodak, Fuji, Ilford, etc), not concerned about reformulating a chemistry that remains very toxic, with products like metol, hydroquinone, potassium thiocyanate, potassium dichromate and other carcinogenic and teratogenic reactants. Digital media, which at first glance seem as something clean and neutral, hide a complex and unsustainable network regarding to the use of resources they made. In addition to the e-waste [3] generated by the planned obsolescence [4] of equipments, there is a whole infrastructure of servers consuming energy and supporting our digital lives. These infrastructures are redirecting their gaze to the ocean, whose state is already critical [5], as a future expansion possibility [6]. At the same time, it is in the digital media where we find the tools to implement this project and that enable us to make the prototypes of the Ecobjects, thanks to the rise of 3D printing. And it is precisely in this dichotomy where we trace the fundamental axes of the project.

Maybe this pursuit is nothing more than the wish to think about different methods in the artistic education field, so that the latter can provide spaces for reflection, so scarce in the technology race in which the majority of the so-called exact sciences are involved, through artistic practices. We understand that in a world flooded by technocracy this critical reflection has become urgent. «Technique only created innovation: washing dishes became easier, but so did killing.» [7] Sustainability and environmental issues can be the basis for a new way of thinking, whether it is scientific, philosophical, economic or artistic.

The teaching of photography in Portugal has a place in several national artistic curricula (high school education and higher education) [8]. In study programmes we can verify that practical training in photography starts with the analogue field. This way, history of photography and its primary analogue techniques gain a significant weight and are the basis for the introduction to digital photography. The camera obscura is one of the elements of history of photography and pinhole cameras are part of the first practical classes in the photographic laboratory. Interacting with this simple device and studying history of photography, the students come into contact with the basic principles of how writing with light (photo-graphy) works.

Thus, our research got two fundamental axes: a) technological-laboratory b) critical-educational. The technological-laboratory axis focuses on innovative technologies and processes, drastically reducing the use of toxic chemistry present in the methods commonly used in conventional photographic laboratories. The laboratory itself is reconfigured to assist the biodegradable processes of photographic capture and development, transforming itself in what we call the Ecolab. This project investigates in an applied way the production of equipment using biodegradable materials that we refer to as Ecobjects. The design and construction of these objects includes the reuse and recycling of plastic and 3D printing. At the same time the critical-educational axis, presents itself like a territory that enhances sustainability problems on the basis of Artistic Education. For this purpose, we planned a series of activities that configure themselves as action-research, in the two only public artistic education schools in Portugal: Escola Artística Soares dos Reis (EASR) and Escola Artística António Arroio (EAAA). This communication refers to the last developments in EASR, specifically, to the production of one of the main Ecobjects, the pinhole. This way, the rethinking of the pinhole takes place considering a set of crucial points: the materials used, its capacity of recycling, the educational specificities for the use of the Ecobject, technical specificities and sustainable and optimised design.

The utility of the pinhole goes way beyond the educational component it entails. The artist Ruth Thorne-Thomsen [9] shows to us the aesthetic potential of the pinhole camera with her extensive artistic work. There is a culture surrounding the pinhole camera [10] which reinforces the significance of this device, that is nothing more than a miniature version of the camera obscura. Maybe it is in this characteristic darkness where we can better understand how light works, thereby understand and master the apparatus [11]. The Ecobject was problematised so it matched the ecological needs of the project with the search of sustainable materials and the opening of new pedagogical possibilities.

During the developing of the Ecobject there were certain features we assumed as fundamental. One of them was the use of the standard format of photographic paper, 10x15 cm, for creating the negative. Thanks to this, it is not necessary to cut the paper or doing any adjustment, which helps reduce the paper waist. Other feature was the attempt of using just PLA in the production of the camera parts, in contrast to other similar projects [12], that use other materials in the camera construction. This decision is a consequence of the context for which this Ecobjects are being designed. These Ecobjects are intended for schools, where resources are often scarce. Thereby reducing the diversity of materials that need to be used, we are also reducing the difficulty of obtaining them.

Finally, section 3 was organised in accordance with the development of the other two versions of the pinhole that were made. Each of them is subdivided in three: «Design/modeling»; «3D printing»; «experimentation/results».

2 METHODOLOGY

In practice the project uses an action-research methodology that reduces the hierarchies of the relationships between the participants, presenting all of them as active researchers of the project. The methodology adopted requires action territories, where ideas are going to be implemented, but that always start from a previous experimental basis. In this sense, after these actions have been implemented, many questions arise that encourage the research and influence future actions. Thus, after analysing the resulting data it is possible to reformulate future actions, thereby generating new knowledge. Following this methodology, we created a plan, according to the school calendar, with the collaboration of the professor Miguel Paiva and students of artistic education in EASR.

Before starting the first work plan with Prof. Miguel Paiva, a first prototype of the pinhole camera V1 was empirically developed and 3D printed. This experience was necessary to test some of the characteristics of the PLA-based 3D filament. Namely its opacity, plasticity and strength. This first pinhole model was tested in EASR with the help and under the supervision of Prof. Miguel Paiva and the results we obtained were positive and promising. This first experience allowed for the creation of a more complex work plan whose goal was to develop a new pinhole model from scratch: the V2 version.

The time and duration of the work plan was two days per week. Every Monday morning and Thursday morning, and it was going to take place during the first school period, which goes from September until December. This work plan initially counted only with the presence of Prof. Miguel Paiva, because the students of the 12th grade were completing an internship during the first period. During this period a «panoramic back» was developed for the V1 version and a new pinhole version, the V2. For the design and development of the new version V2 we used the education version of the software Fusion 360.

The work plan consisted in the making of pinhole by the students. The construction was made using several recycled materials, like cardboard, plastic packaging, wood boxes and shoe boxes. Afterwards they took self-portraits using the pinholes made by the students. During the exercise, the Ecobjects (pinhole) were made available for the students to experiment and understand the differences between the used materials. This experience allowed the understanding of infinite possibilities in the construction of a pinhole. We are not going to use any images of the cameras made by the students in this article due to the page limit.

In these actions we reflect about design and how it shapes the society in which we live in and how it is a fundamental area to initiate small changes in the social systems.

3 RESULTS

3.1 Development of Pinhole V1

3.1.1 Design/Modeling

The design of the first prototype of the pinhole camera V1 started empirically. The simplicity of its fundamental principles allow this type of approach and, consequently, a first prototype was developed using an open-source software, [13] Blender [14]. Blender allows a fast three-dimensional prototyping [Fig. 1], which in this first phase is an advantage. Although for posterior phases it will be more difficult to precise the real dimension of the objects, due to the fact that the box modelling principles of the software do not share the same characteristics of a CAD software. We are not saying that it is not possible to produce Ecobjects using just Blender because there are advanced forms of doing it. We want to emphasise the lack of CAD specialisation the software has, due to its characteristics. Whenever possible we always try to follow the open-source philosophy. However, the CAD options that are available, like for example FreeCAD and OpenSCAD, have a very steep learning curve with lower development levels than other open-source software. In this sense, we choose to use an education license offered by Autodesk with its software Fusion 360. In the long term we will slowly migrate to open-source options producing the respective tutorial documentation.

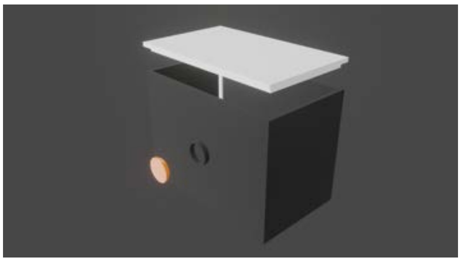

Figure 1. Simple and early pinhole 3d model in Blender software.

One of the first essential characteristics of this first prototype, also mirrored in the following models, was the dimension of the photographic paper we used. On the basis of a sustainable and less waste principle, we designed the pinhole camera according to the size of the standard paper 10x15 cm. This way we avoid cutting the photographic paper to suit the camera dimensions and the whole process generates less waste. To make the introduction of the 10x15 cm photographic paper easier, we designed a frame where it can be introduced, giving us the option of creating margins in the images.

The design of the final model of the Pinhole V1 was done using Fusion 360 [15] because Blender lacks the precision needed to make the fittings of the cover work. In this first model created with Blender, the cover had a simple "L" shaped fitting mechanism. However, this system does not properly protect the pinhole interior of light coming in. So, we developed a cover with a "L" shaped fitting. In view of the characteristics we mentioned earlier, along with a sustainable awareness, the cubic and simple design was changed in favour of a more a trapezoidal design [Fig. 2]. This way we reduce printing time and use of materials.

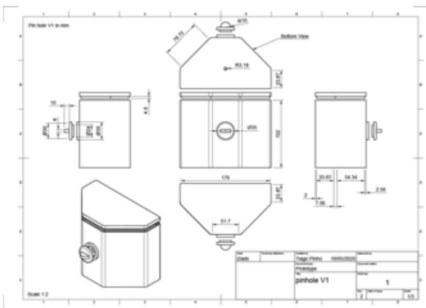

Figure 2. Technical drawing of the pinhole V1 model in Fusion 360.

After making some tests (see section 3.1.3) we developed a curved panoramic back [Fig. 4]. With this back we managed to correct the perspective distortions of the image created on paper. The curved panoramic back, apart from correcting the perspective, helps to even out the exposure in all the image area. This happens because all the photographic paper area is at the same distance of the hole. In a pinhole with a flat panoramic back, not all the paper area is at the same distance from the hole. The centre of the paper is closer to the hole than the ends. Consequently, exposure is not uniform. If the centre of the image is well exposed, the ends are subexposed (darker). This happens because the light has to travel a smaller distance between the hole and the paper placed in front of it (centre of the paper) than the distance the light has to travel from the hole to the ends (which is a bit bigger).

Unlike other 3D printing projects of pinhole cameras [12], in the beginning of the project we want to use PLA as a raw material. In doing so we are able to simplify the construction using just one material and one machine. *It also wants to reflect and discuss the sustainability of this option.* In other line of action, it intends to invest in plastic recycling so it can be used as a raw material in the production of injection moulds and 3D filament production. This design choice enables a better and efficient recycling of Ecobjects in the future. This recycling possibility is framed within the circular logic and philosophy of the Bioimages Project and its goal of constructing an Ecolab. We intend to develop the recycling using specialised machines [16].

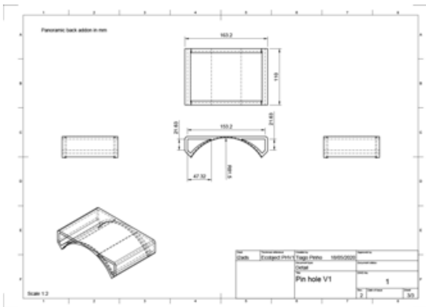

Figure 4. Technical drawing of the panoramic curved back model in Fusion 360.

3.1.2 3D printing

3D printing changed the way we produce objects. Some consider this technology as one of the main components of the third industrial revolution [17]. *"One-off prototypes can be hideously expensive to produce, but a 3D printer can bring down the cost by a huge margin. Lots of consumer goods, mechanical parts, shoes and architects' models now appear in a 3D-printed form for appraisal by engineers, stylists and clients before getting the go-ahead."* [18] Now, small businesses and single individuals are able to develop a prototype or even a product using these machines. Something that was once impossible and required going through several processes which involved several industries and costs.

The first prototype developed using Blender was not printed [Fig. 1]. The aim was to experiment with the concept and verify the technical feasibility with regard to the software. We thought about the problems associated with the materialisation of the object before we started with the printing process. We had to take into account some important aspects: the opacity of the material and the fitting of the top cover of the camera. If we want to be sustainable, we have to foresee, as far as possible, the design problems of an object. We modelled a small box with the same kind of "T" shaped fitting, and we printed it using black PLA. To prepare a 3D model for printing we use a slicer software which analyses and cuts the three-dimensional model. There are several software. For this process we used Cura [19]. In slicer software we choose to use two solid layers of perimeter and 10 % infill, with three solid layers on the bottom and on the top. The box was tested after printing, introducing a bit of photosensitive film in its interior and letting it exposed to the sun for 10 minutes. This way we managed to see if the settings we used in the slicer software and the PLA's opacity were enough not to let the light come into the box. After developing the film, we verified that these settings were letting some light debris in. But not everything went wrong. The "L" shaped fitting worked perfectly.

After this little test, we started developing and printing the pinhole V1 [Fig. 5]. Given that previously the light had managed to pass through two perimeter layers, we decided to double the number of layers. Both, infill and the cubic form were kept at 10 %, which creates an interior extra layer as it is a three-dimensional infill. The cover was printed with 100 % infill because of the use of the orange colour and because, apart from being a small piece, it is the one that ensures that the hole where the lights comes in stays closed.

Figure 5. 3D printed pinhole V1.

3.1.3 Experimentation/Results

We took some images to test it using Cafenol-C with different times, temperatures and concentrations. The first exposure was done in the rear of a house [Fig.6]. We converted the negative into a positive digitalising the negative. It should be noted that the image has a considerable distortion.

Figure 6. House Backyard - First photography taken from pinhole V1 - Positive.

In EASR we made more exposures but this time using the curved panoramic back [Fig. 7]. Looking closely to the vanishing lines and the vertical lines of the windows, we verified that the perspective was corrected. The stains we see in the close-up are rain drops on the window glass. However, there is a small detail present in all images: the contours of the pinhole opening are visible. This happens because of the distance between the hole and the exposure plan, where the photographic paper is. For a focal length considered “normal”, for example, 50 mm, the distance between the hole and the exposure plan has to be equal to the diagonal of the photographic paper that has been used. If that distance is smaller, then we are talking about a “wide-angle” focal length. But if it is bigger, then what we have is “tele” focal length. In this pinhole, the distance between the hole and the exposure plan is smaller than the diagonal of the 10x15 cm paper, so what we have is a wide-angle focal length. However, due to the thickness of the walls, the small diameter of the hole and a short focal length for 10x15 cm, we obtain these rounded borders in the image. It wasn't in our plans but it proved itself as an aesthetic possibility. These images give us the feeling that the spectator is peeking through a lock.

Figure 7. School backyard - EASR - pinhole V1 - Negative.

While we experimented with the pinhole V2, the pinhole V1 was being used by photography students that had made their own cameras using different materials. The challenge was doing a self-portrait exercise [Fig.8].

Figure 8. Student self-portrait- EASR - pinhole V1 - Positive.

3.2 Development of Pinhole V2

3.2.1 Design/Modeling

The starting point of a work program made in collaboration with Prof. Miguel Paiva and the students of his photography classes in EASR, was the design of the pinhole V2 [Fig.9]. We began with the experiences made with the pinhole V1 and we decided to increase our efforts as far as the pinhole's design is concerned, as a pedagogical resource. For this version we established two main objectives: It should pay attention to the distance between the hole and the exposure plan so that the photography could cover all the photographic paper. It should be possible to change the focal distance. This last one represents a pedagogical necessity. If there are two focal lengths available, the students will be able to better understand what the focal length is in the practice and the differences between them during photography training [Fig. 11 e Fig. 12]. During the development we added two more objectives: a filter support in the hole; and the use of two backs, flat normal and curved panoramic.

This time we took into account the distances between the hole and the exposure plan. For the 10x15 cm paper it is 18 cm. This way the image forms itself in the whole area of the photographic paper. Consequently, we achieved a "normal" focal length with enough space to add another length closer to the hole, creating a focal length "wide-angle". This length allows us to create pinhole sub-models with different focal lengths. However, for this design it is only possible to use the flat back. Due to its form, the panoramic curved back occupies more space.

Compared with the previous design, we experienced some setbacks, namely the fact that we did not use the "T" shaped fitting system. It was necessary to make some sacrifices to test the pinhole with the students during the practical classes. We focused our attention in the development of the four main principles and we decided to proceed with the printing process of the model to test the new functionalities. In fact, this model represents a midpoint in the development process of the final version. However, due to the restrictions caused by the COVID-19 pandemic we could not proceed with the development and experimentation with the students, since all schools closed.

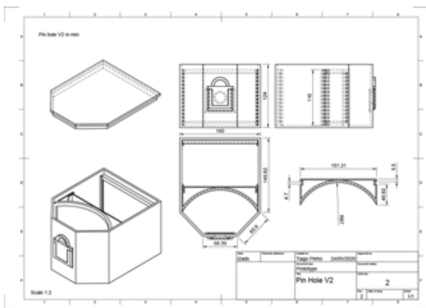

Figure 9. General technical drawing of the pinhole V2.

3.2.2 3D printing

The printing process of the V2 version "Fig.10" took twice as long as V1 version. Nonetheless, we didn't spend twice as much in the materials, even though the pinhole was bigger. And all thanks to the reduction and optimization of the wall thickness. In general, this model takes longer to print than the previous version. A time increase can lead to a smaller and portable version of the pinhole. We kept a 100% infill for the cover of the hole and at the same time, we kept the settings for the perimeter of the body and the cover. We reduced the quality and increased the layer height from 0.2 mm to 0.28 mm, compared to version V1. These obstacles give us the opportunity of using a 0.6 mm diameter nozzle instead of a 0.4 mm we are using now. Printing times are drastically reduced at the expense of the finishing quality. But this is not a substantial problem because we think of 3D printing technology and the Ecobjects as functional prototypes, where finishes are a secondary and irrelevant aspect.

Figure 10. 3D printed pinhole V2.

3.2.3 Experimentation/Results

During the first experimentation we did with this pinhole version in the exteriors of the EASR, there was a light infiltration through the pinhole's cover because we didn't used the "T" shaped fitting and some warps that appeared in the piece during the printing process. This problem was temporally resolved using black adhesive tape in the edges of the cover. We understood the advantages of a "T" shaped design compared to a "L" shaped design. The most relevant results of the V2 version of the pinhole were the images we managed to take, making use of the two different focal lengths we had available. These two examples [Fig.11 y Fig. 12] help the student to understand that a photography taken at the same place, but using two different focal lengths, results in two different framings for the same image. And when we use the two different backs, the differences are even greater.

Figure 11. School backyard- Panoramic curved back at wide focal distance - Negative.

Figure 12. School backyard- Normal back at normal focal distance - Negative.

3.3 Redesigning the pinhole camera as a metaphor for the design of tomorrow

If we analyse the way society is structured, we can verify many mechanisms/systems that have been optimized throughout the times in favour of accomplishing an objective, whether it is related to economy, power, political or education. These mechanisms are drawn in order to become the most efficient possible. The design of such mechanisms is often camouflaged in themselves, and in the naturalization of their implementation and/or use. They are black boxes, so obscure that we only need to generate an input and wait for its output [20]. In this seemingly simple exercise of redesigning the pinhole camera, we become aware of the mechanisms present in the way we do and think about the design. The fact that the design is submitted to the current capitalist neo-liberal model [21] is, very often, softened by diverse external factors resulting from other areas, that want to keep the continuity of certain social and economic models. “In this aspect, the design is a perfect model of the neo-liberal subjectivity: each designer is trained to behave like a company of only one person, thinking the world in terms of briefings, clients, budget and so forth”. [22]. To think about other design solutions for the complex mechanisms becomes a herculean exercise. However, if we focus our attention on something simpler like a pinhole, we could maybe make a kind of “reverse engineering”, in this case, a “reverse designing” of the mechanisms, to better understand how such complex mechanisms work. In this complex reversion, we verify that there are design alternatives, not only for the function and shape of the objects, but also for the system itself, where the objects cohabit. Thinking a priori about the design of the system and its principles, is extremely important because it shapes the way we will draw the objects of that system. In every tree, there is always a root. And it is from that root, which serves as a foundation, that an entire complex system sprouts. The implementation of a system with a circular and sustainable thinking, dictated the whole ecosystem of the Bioimages creation, in which the Ecobjects play a fundamental role in the materialization of these aspirations and wills.

4 CONCLUSIONS

The inclusion of teachers and students in the action-research process, promotes an essential laboratory environment that allows us to focus on the issues present in the daily life of a school. The artistic education promotes this de-hierarchized space, providing new ways of searching for knowledge. The 3D printing technology allied with the open-source movement, establishes an unprecedented connection between the physical and the digital world, and promotes new potentialities. The pinhole design and use process, which combines digital and analogue photography techniques, allows new ways of learning and more tangible links to the virtual and physical world. New pedagogical potential, new forms of experimentation and new possibilities of artistic practices have emerged without a doubt. With these alternatives we can rethink the way we do design, while reinventing from old systems, through circular and sustainable logics that resist against mass production and consumption, but also the programmed obsolescence of this phase of neoliberal capitalism. Especially, the making of an image becomes thought, awareness and imagination of a more sustainable world. Due to this pandemic situation, resulting from the spread of covid-19, physical contact was reduced, causing setbacks to the development of the project based on and action-research methodology. However, once again, with future works in mind, we propose to analyse the potential that may arise from this drastic change that transformed physical working relations into digital relations. Given the impossibility of students and teachers being physically present, we propose to rethink this distanced contact at distance in a network for sharing experiences related to these problems. We can think of solutions that seek a collective network and not a network of individualisms that revolve around the image, as is usual in so-called “social” networks. We also think about understanding the pedagogical aspects of this prototype by digitally simulating the photography procedures of a pinhole. As mentioned earlier, the use of open-source software is a philosophy that we intend to consolidate in practice, and in this global village confinement situation, the use of Blender software can present itself as an exceptional pedagogical tool. As we can see in this example [23], Blender’s Cycles render engine is capable of simulating how light reacts in the real world, and thus, makes it possible to simulate the operation of a pinhole in digital environments. This, combined with the fact that almost everyone can print the pinhole in 3D and test it in their home, and that everyone can have an Ecolab and produce their own sustainable images, translates into the fact that the physical distance imposed by the confinement can be shortened by an experience that gives us back the physicality of the image.

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