Universitat Oberta de Catalunya

artnodes
E-JOURNAL ON ART, SCIENCE AND TECHNOLOGY

https://artnodes.uoc.edu

ARTICLE

NODE «IN THE LIMITS OF WHAT IS POSSIBLE: ART, SCIENCE AND TECHNOLOGY»

Sculpture and New Technologies in Scientific Educational Outreach: 3D Foraminiferal Models as a Referent of Ocean Acidification and Climate Change

Víctor G. Peco
Complutense University of Madrid
Nerea Garzón-Arenas
Complutense University of Madrid
José Carlos Espinel
Complutense University of Madrid
Concha Herrero
Complutense University of Madrid

Date of submission: March 2021
Accepted in: May 2021
Published in: July 2021

Recommended citation

G. Peco, Víctor; Garzón-Arenas, Nerea; Espinel, José Carlos; Herrero, Concha. 2021. «Sculpture and New Technologies in Scientific Educational Outreach: 3D Foraminiferal Models as a Referent of Ocean Acidification and Climate Change». In: González Díaz, Paloma; García Méndez, Andrea (coord.) «In the limits of what is possible: art, science and technology». *Artnodes*, no. 28: 1-11. UOC. [Accessed: dd/mm/yy]. *http://doi.org/10.7238/a.v0i28.385398*

Abstract
The Foraminifera Project is a collaboration between researchers of the Faculty of Fine Arts and the Faculty of Geological Sciences at the Complutense University (UCM, Madrid, Spain). The work, based on scientific dissemination through art, is framed in the theme "Climate change

and Ocean Acidification" as part of the course "Art, Science and Nature" of the Master's Degree in Research in Art and Creation (Faculty of Fine Arts, UCM). The team used recent sediment samples from Indian Ocean and Red Sea that contained healthy and unhealthy foraminifera specimens to create 3D specimen models. These models were made using traditional sculpture techniques, photogrammetry, and 3D printing to show different states of foraminifera dissolution and corrosion from ocean acidification. The end result of this project resulted in nine interactive pieces which were part of the exhibition "Drift & Migrate" open to the public during the month of November 2019 in the exhibition hall of the Faculty of Fine Arts (UCM). The 3D models of foraminifera were displayed with educational graphics and blind-accesible explanatory signage (Braille) to share the scientific facts of foraminifera and their role in the ocean ecosystem. The main objective of the collaboration is to raise awareness of anthropogenic effects on foraminifera and the marine ecosystems in general and to expand research opportunities between the arts and sciences at the university.

Keywords
foraminifera, sculpture models, education, climate change, 3D technologies.

Escultura y nuevas tecnologías en la divulgación científica y educativa: Modelos 3D de foraminíferos como referentes de la acidificación de los océanos y el cambio climático

Resumen
*El Proyecto Foraminifera es una colaboración entre investigadores de la Facultad de Bellas Artes y la Facultad de Ciencias Geológicas de la Universidad Complutense de Madrid (España). El trabajo, basado en la divulgación científica a través del arte, se enmarca dentro del tema «Cambio climático y acidificación de los océanos» como parte del curso de posgrado «Arte, Ciencia y Naturaleza» dentro del Máster en Investigación en Arte y Creación de la Facultad de Bellas Artes (UCM). El equipo usó muestras de sedimentos actuales procedentes del océano Índico y el mar Rojo que contenían ejemplares de foraminíferos sanos y afectados por disolución y corrosión para la creación de modelos en 3D. Estos modelos se realizaron utilizando técnicas tradicionales de escultura, fotogrametría e impresión 3D para mostrar los diferentes estados de disolución y corrosión en foraminíferos producidos por la acidificación de las aguas de los océanos. El resultado último de este proyecto es una obra formada por nueve piezas interactivas que formó parte de la exposición titulada «*Drift & Migrate*» expuesta en la sala de exposiciones de la Facultad de Bellas Artes en el mes de noviembre de 2019. Los modelos 3D de los foraminíferos se exponen junto a gráficos didácticos y señalización explicativa accesible para personas ciegas (Braille) que muestran los datos científicos sobre los foraminíferos y el lugar que ocupan en los ecosistemas oceánicos. El objetivo principal de esta colaboración es sensibilizar y alertar del impacto antropogénico sobre los foraminíferos, y en los ecosistemas marinos en general, y ampliar las oportunidades de investigación entre las artes y las ciencias en el marco de la universidad.*

Palabras clave
foraminíferos, modelos de escultura, educación, cambio climático, tecnologías 3D

Introduction

Art & science: The foraminifera project

Art and Science have always been very closely interconnected. Throughout history, artists have been inspired by nature, and scientists have used art to understand and record their observations (Espinel, Parker, and Espinel-Velasco 2020, 13). When we talk about scientific illustration, we are referring to a very detailed type of drawing, with the purpose of visually reaffirming the texts of researchers from various scientific disciplines, such as astronomy, archeology, medicine, botany or zoology. In other words, the main aim of scientific illustration is to communicate and express specific information and scientific knowledge.

From bestiaries to encyclopedias, expeditions and travel stories have made us aware of our environment, instigating us to approach nature through science. At the same time, scientific illustration has become a source of inspiration for artists, and in some ways, it gives us

Figure 1. (a) Foraminifera modelled on clay. (b) Visitors at the exhibition interacting with the 3D printed models. (c) General overview of the artwork, 2019.

another vision of our environment. It serves a wide range of functions, from purely anatomical descriptions targeting a very specific audience, to more general representations and descriptions for a broader, and not necessarily expert, audience. With new technology, we can now complement 2D renderings with 3D models to enhance and expand teaching, learning, and research opportunities across the arts and sciences (Figure 1).

The main objective of this work is to carry out a collaborative art-science project to raise awareness of the problems caused by climate change, in particular, water acidification in marine ecosystems, based on the realisation of 3D models of specimens of a group of microscopic marine organisms, the foraminifera, frequent in recent marine sediments. The shells of this group show corrosion and dissolution under acidic seawater conditions.

What are foraminifera and their applications?

Foraminifera are single celled microscopic organisms with connecting pseudopodia (extensions of the cytoplasm). They have an external shell called test that can be organic, agglutinated or calcareous. The test presents one or more cavities (the chambers) separated by walls called septa. The chambers are connected by holes in the septa named as foramina, from which the name foraminifera derives (Boersma 1998, 21). The test protects the cell and reduce biological, physical and chemical environmental stress. Living foraminifera are aquatic organisms that live in all marine environments and can be found in a wide array of environments, from the tropics to the poles; nevertheless, each species is adapted to distinctive physical and chemical environmental parameters. They have probably existed since Ediacaran times (Gaucher and Sprechmann 1999, 55), being agglutinated simple tubes from earliest Cambrian times (541 Ma) the oldest known fossil foraminifera (McIlroy, Green, and Brasier 2001, 13). Foraminiferal tests can be very abundant in modern oceans representing over 55% of Arctic biomass and over 90% of deep sea biomass (*fide* Armstrong and Brasier 2005, 142). Their abundance in sediment samples may reach tens of thousands specimens per square meter, and their diversity may exceed 60-70 species in a sample of 300 individuals in tropical environments (*fide* Culver 1993, 203).

Living and fossil foraminifera are mainly studied by micropaleontologists and are the most important protozoans for solving geological problems. They are one of the best groups to date and correlate marine sedimentary rocks; they are used to interpret past environments of Phanerozoic; and, they are applied to estimate the temperatures of ancient oceans and to investigate other paleoceanographic and paleoclimatic proxies such as productivity, nutrients, currents, depth and changes in sea level. Besides, they are also very useful in the study of environmental impacts, since they are very sensitive to organic and metal contaminants in shallow marine and coastal waters, and therefore are used in pollution monitoring, tracking down the degradation of marine ecosystems. Moreover, their tests are commonly made of calcium carbonate and are therefore sensitive to dissolution caused by acidification, making them excellent tools in global warming and climate change research.

Ocean Acidification (OA) occurs following the CO2 enrichment of ocean waters due to the increase of atmospheric CO2, which causes the decrease of pH and carbonate saturation of the seawater. Foraminifera have been shown to be vulnerable to the effects of OA, through significant changes in the composition and structure of their assemblages (Dias et al. 2010, 845). Experimental and in situ foraminiferal studies (see Keul et al. 2013, 6185-6186; and Kawahata et al. 2019, 9-14, for a review), have shown that OA can cause the following results in these protozoans: a) decrease of calcification with lighter and thinner shells; b) negative effects in growth, physiology and survivorship of the organisms; c) shell corrosion and dissolution; and, d) decline in abundance and diversity, more pronounced in calcareous than in agglutinated taxa. Furthermore, foraminifera can be absent in environments with seawater pH<7.9 (Uthicke, Momigliano, and Fabricius 2013, 1). General dissolution features reported in literature include (see Herrero and Canales 2002, 31-33): dull, pitted and etched surfaces, loss of the last chambers with reduction in test size, selective dissolution affecting ornamentation; enlargement of the pores, coalescing pores and complete loss of the outer test wall.

Examining foraminifera requires biological or petrographic microscopes, stereoscopic microscopes and scanning electron microscopes, technologies which are not within reach of most part of the population and are mostly limited to research institutes or laboratories. Similarly, in secondary and higher education where the classes have a large number of students, it is not always possible to explore the natural world with these techniques, due to time constraints. It is here that hand-sized replicas, casts and 3D microfossil models are a perfect tool for teaching and communication purposes. Models are also very useful in training people with functional diversity in non-formal education. There are several 3D model collections of foraminifera in museums and universities around the world, some of them made by 19th century researchers; models are usually made of white or colored plaster.

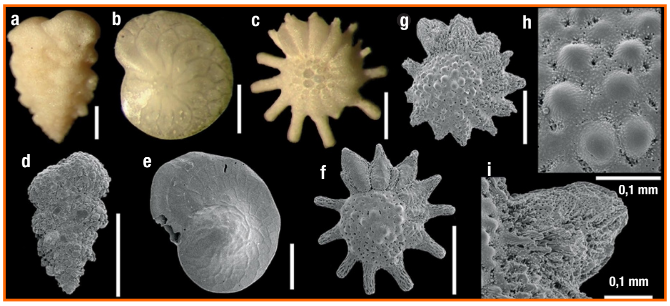


Figure 2. Recent foraminifera from Maafushivaru house reef: (a-c) Specimens used as reference under binocular stereoscopic microscope. (a) *Textularia*. (b) *Heterostegina*. (c) *Calcarina*. (d-f) Other specimens used as reference under SEM. (d) *Textularia*. (e) *Heterostegina*. (f) *Calcarina*. (g-i) Specimen of *Calcarina* with corrosion and dissolution due to acidification. (g) General view. (h) Detail of the central surface of the shell. (i) Detail of a corroded spine. Unless specified, scale bars 0.5 mm.

Material and methods

We study specimens of recent foraminifera from Red Sea and Indian Ocean selecting the sample M-15 that was collected by scuba diving at 15m depth in front of the NE channel of Maafushivaru house reef (South Ari Atoll, Maldives). The sediment sample contains calcified segments of the thallus of *Halimeda* (benthic genus of macrogreen algae), triaxon siliceous spicules of sponges, fragments of branching calcareous skeletons of bryozoan (sessile colonial marine invertebrates), abundant fragments of corals and claw crabs, plates and spines of echinoids (sea urchins), juvenile specimens of gastropods and bivalves, valves and carapaces of ostracods (tiny benthonic crustaceans known as seed shrimp), planktonic foraminifera and a diversified fauna of benthonic agglutinated and calcareous foraminiferal taxa.

We hand-picked the foraminiferal specimens with a fine brush under binocular stereoscopic microscope Leica M-12. We chose three specimens according to their sculptural morphology, technical complexity and future artistic reproduction, considering the time available for the development of the project. We analysed the shell composition, test growth, chamber shape, ornamentation and other morphological elements of these specimens in order to establish the relevant and diagnostic features to be taken into account in the clay models. Figures 2 a-c show the three specimens of foraminifera used for making the 3D teaching models; we photographed them under a binocular stereoscopic microscope with a digital camera (Olympus Tough TG-4). The first one has an agglutinated shell (genus *Textularia*), and the other two have calcareous shells (genera *Heterostegina* and *Calcarina*, respectively). As shown in Figure 2, the specimens were of small size (≤ 2mm) and two of them presented quite a big volume causing small depth of field in the microscope and out of-focus-pictures. To bypass this difficulty, we used Scanning Electron Microscope (SEM) images of other specimens of the same taxa from samples M-13 and M-15 of Maafushivaru house reef (Figures 2 d-f); this technique allows seeing accurately the test textures and ornamentations. Similarly, optic and electronic pictures of the foraminiferal taxa from literature and the 3D models of *Calcarina* included in the digital morphology library (Olori 2004), were also used as reference material. Besides, we photographed partially dissolved foraminiferal shells of *Calcarina* sp. from sample M-16 (Maafushivaru house reef) under SEM to observe and exemplify the corrosion and dissolution due to acidification (Figures g-i).

Based on these reference specimens, we made three models in *Monster* modelling clay (Figure 3a). This material can achieve a high quality of detail and hardens with the cold, returning to a malleable state after recovering the optimal temperature, which allowed us to manipulate and reposition the models without damaging them. The main drawback during the modeling was to accurately capture the surface texture and ornamentation of the specimens, which could be adequately resolved thanks to SEM photographs.

The *Textularia* specimen had the extra difficulty of creating a realistic grainy texture (Figure 3b), because these foraminifera build their shell by clumping together sand-sized grains and other small particles. This texture was emulated by melting the clay and splashing it on the model with an operating room brush. Up to three follow-up sessions were held between artists and scientists at different stages of development until the intended result was reached with sufficiently scientific rigor.

Once the models were approved, photogrammetry was performed to create a 3D digital mesh. For this, the clay models were strung with a metal shank and attached to a wooden base (Figure 3c). We took photographs placing the sculptures on an automatic rotating platform, which was synchronized with a Canon EOS 40D camera through an Arduino device. Light needed to be reinforced to obtain optimal images for the photogrammetric process. Indirect natural light was complemented with two 45º spotlights with diffuser located in the same plane of the camera, one on each side of it, to be able to close the diaphragm without the exposure speed implying loss of definition due to vibrations. The camera was connected with a trigger cable to the base to synchronise the shots with the arrest of the rotating base (see Figure 3c).

Figure 3. Creative process: (a) Clay modeling. (b) *Textularia's* wall surface detail. (c) Layout for *Textularia* photogrammetry in the "set". (d) Explanatory and inclusive signage. (e) View of models (upper three healthy and lower three with corrosion and dissolution) in interface of Blender. (f) 3D print with supports and 3D clean print of *Calcarina*. (g) 3D healthy prints of *Calcarina, Heterostegina* and *Textularia*. (h) 3D prints with acidification effects of *Textularia, Heterostegina* and *Calcarina*.

The photographs were taken in RAW format (digital negative or "raw" images). Adjusting the focal length parameters (distance between the photographic sensor and the lens aperture) to 55mm to avoid distortion in the image, with a sensor sensitivity of the camera at 100 ISO, 18 aperture (to gain depth of field and avoid loss of sharpness by diffraction), and locking focus after pre-focusing so that the same plane was always defined. This process was repeated three times for each one of the models at different heights: at the object level, elevated view and seen from below, thus creating three imaging rings.

We performed batch processing of all RAW shots to convert them to JPG format with Canon Digital Photo Professional software, which uses a compression system with which format conversion produces minimal loss of sharpness. Although RAW files take up a lot of memory, they present better quality of sharpness compared to a high definition JPG file (in JPG the camera software compresses the image which implies some loss of sharpness). We loaded the images into the AliceVision programme, to generate the 3D mesh. This mesh was exported in .OBJ extension to be processed in Meshlab software, where the Clustering and Decimate actions were carried out to reduce its weight without losing resolution. Finally, the files were exported in .STL extension for subsequent digital processing. We fixed the mesh errors by opening the .STL files in the 3D Builder program included in Windows 10.

We remodelled the meshes in the same Blender program in which the morphological errors resulting from photogrammetry had been fixed, leaving the digital models as similar as possible to those produced in clay (Figure 3e). Once all the changes had been made, the digital models of the healthy specimens were printed in white Polylactic Acid (PLA) at 220ºC with a "skirt" type holding platform, with supports at 30º in the Witbox 2 printer at 60% printing speed, at 0.1 mm layer height and with a 30% filling. We chose PLA because it is a resistant, light material and with the possibility of reproducing the detail necessary for the work to be inclusive, this being also a biodegradable material (Figure 3f).

Regarding the specimens affected by corrosion and dissolution (specimens exposed to seawater acidification), we made a copy of the files for their subsequent modification in Blender. Once the digital modelling process was completed to achieve the morphologies affected by corrosion and dissolution, they were 3D printed with the same parameters but in transparent and unfilled PLA, thus emulating the thinning and brittleness of the shell of these acidification product specimens (Figures 3g-h).

Results and discussion

The whole process, as can be seen in Figure 4, reflects the close relation between arts and science. The final result of this project resulted in 9 pieces which were part of the exhibition "Drift & Migrate" open to the public during the month of November 2019 in the exhibition hall of the Faculty of Fine Arts of the Complutense University of Madrid. The topic of the exhibition was the water acidification caused by the concentration of CO_2. To talk about this issue in relation to Foraminifera, we decided to use sculpture as it seemed to be the artistic discipline that best allowed us to represent these organisms and the impact of water pollution in their shells. In addition, we considered that the three-dimensional nature of sculpture, that allows a 360º visualization and tactile exploration of the specimens, was the most inclusive method considering the public to whom our work was addressed. Other techniques such as photography, drawing or painting may be more effective in representing environments and ecosystems, but their two-dimensional nature prevents the transmission of information through the sense of touch.

For the assembly of the pieces in the exhibition room, we designed metal supports (similar to those used in science museums to hold bones) to embrace the 3D models of transparent foraminifera (those subjected to acidification and affected by dissolution) to hold them on a black wall, on which they stand out as the metal structure was camouflaged. The 3D models of white foraminifera (healthy speci-

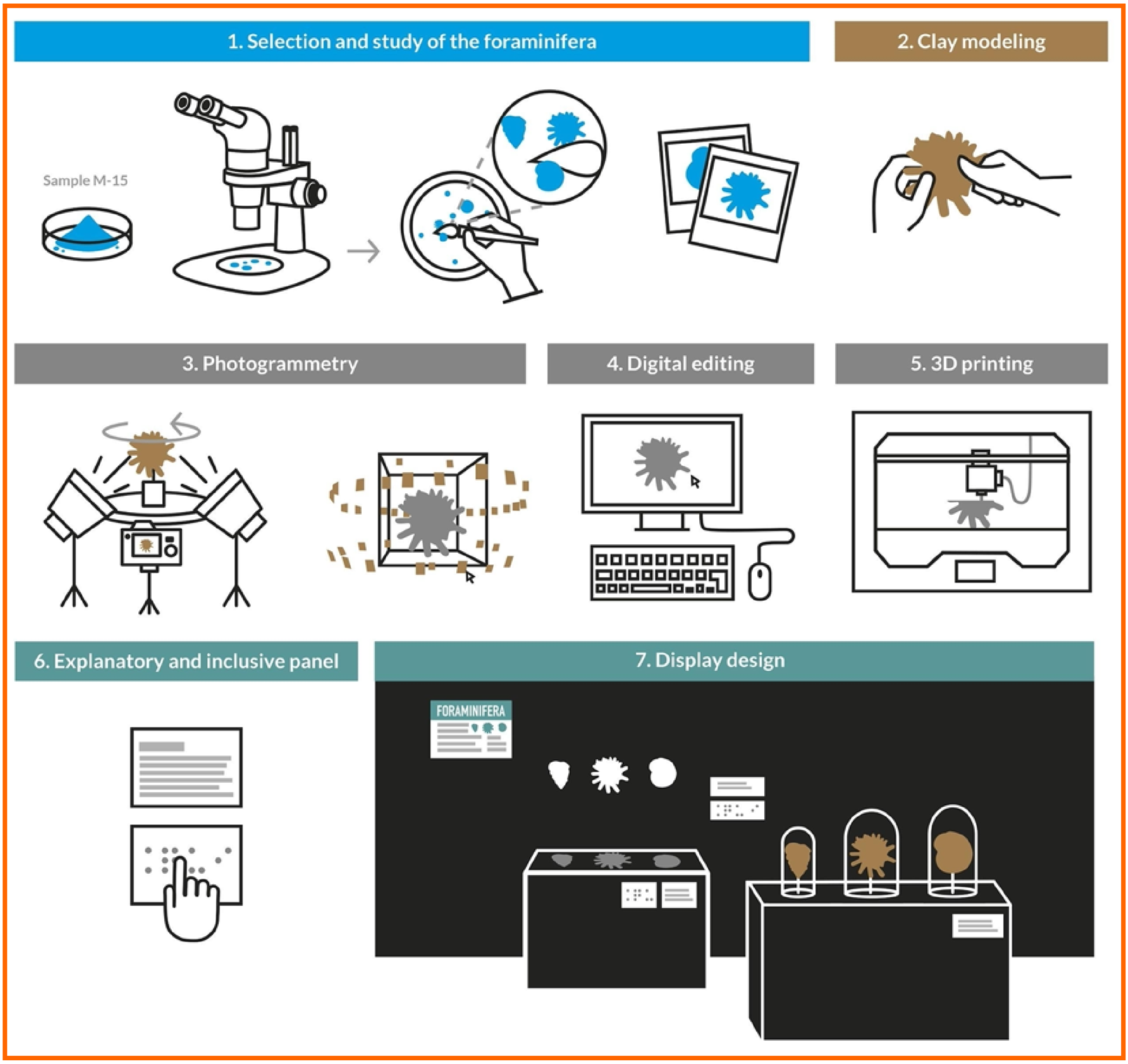


Figure 4. Complete process infographic, 2020.

mens) were exhibited on a base. On the upper part of this element, we drew the silhouettes of the foraminifera to be placed and with a small perforation we passed a nylon thread, which was knotted at a small weight in one side and to the 3D printed piece in the other, so that the sculptures returned to the point of origin coinciding with their silhouette, this way public in the exhibition could touch and pick up the pieces. We assemble each modelling clay model inside a glass bell, and place them a few meters ahead of the 3D prints so that they could be seen in 360°.

Each element was accompanied by blind-accessible explanatory signage (braille) produced through light-sensitive photopolymer plates in collaboration with the National Organisation of Spanish Blind people (ONCE) (Figure 3d).

The selection of foraminifera for this artistic work is due to their importance in scientific research on water pollution and climate change in recent marine ecosystems, and to the varied morphologies of their shells, perfect as sculptural works. In addition, it was a challenge from an artistic point of view since their study requires very specific and special techniques such as the stereoscopic microscope or the scanning electron microscope. This microscopic character of foraminifera is also responsible for the fact that they are little known to the general public.

The development of this work has been carried out thanks to the continuous exchange of information among the members of the multidisciplinary team to achieve macroscopic sculptural representations with scientific rigor. Direct observation, drawings and photographs under stereoscopic microscope, SEM photographs and published literature were especially useful to make a proper interpretation of the complex and subtle morphologies of foraminifera: their chamber arrangement and ornamentation, the surface texture, and dissolution and corrosion processes due to water acidification.

The process began with traditional modeling of the foraminiferal shells as it was not possible to digitise such small specimens. Thus, we found that the flow of information was faster and more accurate as we physically intervened on the sculptures as we made observations under the stereoscopic microscope. Another advantage of sculpting the specimens by hand is that the process of creation was directly linked to the process of exploration and reception of information by the public. In this way, the morphology and texture of the shells of the foraminifera were presented with an appropriate execution suitable for active interaction with the visitors of the exhibition. The tiny and delicate details of the shell textures were continuously revised to make them perceptible to the touch. The digital creation of the models of foraminifera affected by dissolution was made from the healthy specimens, preserving the latter. In this way the models were presented two by two in the final artwork to highlight the visual and tactile comparison of morphologies between healthy and unhealthy specimens of the same genus. Digital technology enabled this replication of the models by translating the virtual objects into the physical world through 3D printing. Although blind people may not recognise the chromatic difference between the specimens, the lightness and sense of fragility of the 3D models in transparent PLA printing is appreciable due to the absence of infilling material.

The artistic but accurate representation of foraminifera on a macroscopic scale using 3D models allows accessibility to a greater number of people, especially those with poor or a lack of vision who cannot look through a microscope. In this way, another important objective can be fulfilled, which is to raise awareness about ocean acidification in an inclusive and accessible way.

Conclusions

The work presented, an interactive art-piece made up of visual and tactile 3D-models of foraminifera that communicate the degradation of species and an awareness of the impact of Ocean Acidification, converses with a process of degradation. Starting from pieces modelled rigorously by hand and that, inevitably, in the creative process used, they are degraded in a deliberate but also unintended way, as information is lost at each step of the modelled-scanned process. This creative process implies the degradation of objects that, in addition, have been developed in a material (PLA) that is biodegradable and sensitive to factors such as heat or humidity in the environment, becoming a simile of the degradation process suffered by organisms that inhabit the marine environments.

Multidisciplinary collaborations in arts and science research can bring significant benefits to society. Our combined efforts brought new understanding of the anthropogenic environmental repercussions suffered by foraminifera (in particular) and marine ecosystems (in general) due to climate change. These methods of artistic-scientific research raise awareness of different issues, which is especially important since it is only possible to protect what is known, making it's possible to work in order to find solutions.

It is necessary to support collaborations between art and science, to promote awareness and a positive change in society regarding climate change and other anthropogenic impacts on the environment. The art-science collaboration allows, through different approaches, and always with scientific rigor, to create discourses full of nuances that awaken the interest of the public.

Acknowledgments

We appreciate the knowledge, time and space provided by Dr. Pablo de Arriba del Amo (Fine Arts College, Complutense University of Madrid) during the processes of digitizing and 3D printing the models. We would also like to thank Dr. Nadjejda Espinel-Velasco for reviewing the text and helping with its translation, and also to Professor Jennifer Parker (University of California Santa Cruz, USA) for the opportunity to present our project with The Algae Society, the idea of writing this article and for the review of the final manuscript. The authors also wish to thank Dr. Ana Vicente Montaña from the National Center for Electron Microscopy (UCM) for helping with the SEM photographs. We also thank the National Organisation of the Spanish Blind (ONCE) for supervising the texts translated into Braille. Finally, we acknowledge the teachers from Artediez School (Madrid): Marta Matías for the advice and workspace for creating inclusive material; Nacho Clemente and Ártemis Ruipérez for the review of the graphic material that accompanies the exhibition.

References

Armstrong, Howard A., and Martin D. Brasier. *Microfossils*. Oxford: Blackwell Publishing, 2005. DOI: https://doi.org/10.1002/9781118685440

Boersma, Anne. "Foraminifera." In *Introduction to marine micropalaeontology*. 19-77. New York: Elsevier North-Holland Inc, 1998. DOI: https://doi.org/10.1016/B978-044482672-5/50002-7

Culver, Stephen J. "Foraminifera." In *Fossil prokaryotes and protists*. 203-247. Boston: Blackwell Scientific Publications, Inc, 1993.

Dias, Ben B., Malcom B. Hart, Christopher W. Smart, and Jason M. Hall-Spencer. "Modern seawater acidification: the response of foraminifera to high-CO2 conditions in the Mediterranean Sea." *Journal of the Geological Society of London* 167 (2010): 843-846. DOI: DOI: https://doi.org/10.1144/0016-76492010-050

Espinel, José Carlos, Jennifer Parker, and Nadjejda Espinel-Velasco. "Science and Collectivism in Artistic Creation: Embracing Climate Change through Art." *The International Journal of The Arts in Society: Annual Review, Common Ground*. Volume 14, Issue 1 (2020): 11- 20. ISSN: 1833-1866 (Print), ISSN: 2473-5809 (Online). https://doi.org/10.18848/1833-1866/CGP/v14i01/13-20.

Gaucher, Claudio, and Peter Sprechmann. "UpperVendian skeletal fauna of the Arroyo de Soldado Group, Uruguay." *Beringeria* 23 (1999): 55-91.

Herrero, Concha, and María Luisa Canales. "Taphonomic processes in selected Lower and Middle Jurassic foraminifera from the Iberian Range and Basque-Cantabrian Basin (Spain)." *Journal of Foraminiferal Research* 32 (2002): 22-42. DOI: https://doi.org/10.2113/0320022

Kawahata, Hokada, Kazuhiko Fujita, Akira Iguchi, Mayuri Inoue, Shinya Iwasaki, Azumi Kuroyanagi, Ayumi Maeda, Takuya Manaka, Kazuyoshi Moriya, Haruka Takagi, et al. "Perspective on the response of marine calcifiers to global warming and ocean acidification—Behavior of corals and foraminifera in a high CO_2 world "hot house." *Progress in Earth and Planetary, 2019. Science*. DOI: https://doi.org/10.1186/s40645-018-0239-9.

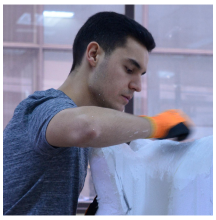
Keul, Nina, Gerald Langer, Lennart J. de Nooijer, and Jelle Bijma. "Effect of ocean acidification on the benthic foraminifera Ammonia sp. is caused by a decrease in carbonate ion concentration." *Biogeosciences* 10 (2013): 6185-6198. DOI: https://doi.org/10.5194/bg-10-6185-2013

McIlroy, Duncan, Owen R. Green, and Martin D. Brasier. "Palaeobiology and evolution of the earliest agglutinated Foraminifera: Platysolenites, Spirosolenites and related forms." *Lethaia* 34 (2001): 13-29. DOI: https://doi.org/10.1080/002411601300068170

Olori, Jennifer. "Calcarina sp." (Online), *Digital Morphology* (2004). Accessed in February 2020. http://digimorph.org/specimens/Calcarina_sp/.

Uthicke, Sven, Paolo Momigliano, and Katharina E. Fabricius. "High risk of extinction of benthic foraminifera in this century due to ocean acidification." *Scientific Reports* 3 (2013): 1-5. DOI: https://doi.org/10.1038/srep01769

CV



Víctor G. Peco
Graduate in Fine Arts and Master's in Advanced Paleontology from (UCM) Complutense University of Madrid
victor06@ucm.es

Young paleoartist with a preference for sculpture, trained in Fine Arts and specialisation in Paleontology. His work is focused on the investigation of current and extinct organisms, to develop sculptures that rigorously reconstruct the appearance of past faunas based on scientific data. He has been a beneficiary of the summer artistic creation scholarship programme offered by the Complutense University of Madrid (UCM), where he also has work in the Gabinete de Medalla belonging to the Department of Sculpture and Art Education at the Faculty of Fine Arts (UCM), and where he has worked as Honorary Collaborator. He has also made publications and workshops related to scientific dissemination in the area of Earth Sciences, in addition to group art exhibitions, one of them linked to the 2019 United Nations Climate Change Conferences (COP25). He is currently exploring the possibilities of virtual paleontology, and searching for more environmentally friendly processes of artistic creation. All this is structured within the framework of scientific dissemination to transmit through these artistic-scientific processes, paleobiological research in an accessible way to society.

Nerea Garzón Arenas
Graduate in Fine Arts from (UCM) Complutense University of Madrid (specialising in Photography and Sculpture) and Superior Technician of Art and Design in Graphic Print from Artediez School.
negarz01@ucm.es

Nerea Garzón Arenas is a visual artist and graphic designer. Her pieces explore the potential of light, colour and form, focused on natural or daily elements redefined through the lens of her camera. Some of these works have earned her awards in the Concurso de Artes Plásticas for the Hotel Four Seasons in Madrid (2017, 2018 and 2019), among other mentions. With a multidisciplinary approach she created projects related to nature and education, to explore and learn, collaborating with professionals using environmentally friendly materials. The development of her artistic skills has allowed her to collaborate and participate in collective exhibitions, for example in the framework of the UN Climate Change Conference COP25 (2019). She was beneficiary in different calls for artistic creation and training linked to the UCM, being granted a scholarship in the Department of Sculpture and Art Education at the Faculty of Fine Arts or participating in a summer artistic creation scholarship. Moreover, she has an Anatomical Drawing belonging to the Gabinete de Dibujos in the Department of Drawing and Printmaking. Currently, she combines her artistic work with a Training Scholarship in the management of Historical-Artistic and Scientific-Technical Heritage at Complutense University of Madrid.

José Carlos Espinel
Lecturer at Complutense University of Madrid
Faculty of Fine Arts. Department of Sculpture and Art Education.
jcespinel@ucm.es
ORCID: 0000-0002-5990-9249

PhD in Fine Arts with a focus on Art and Digital Technologies. José Carlos is an experimental and multidisciplinary artist and designer, with a particular interest in mixing digital and traditional technologies. His artistic production is very diverse and includes 3D printed sculptures, artist books, interactive installations, video art or video games. José Carlos's research and artistic interest are focused on ecology and social justice, and this is clearly reflected in his most recent works, exhibitions, publications and conferences. He is a founding member of The Algae Society, an international group of artists, scientists and scholars, focused on cooperate, experiment, design and exhibit work related to climate change and ocean acidification (www.algaesociety.org). He is also founding member of the "Arte, Tecnología y Compromiso Social - ARTECO" (Art, Technology and Social Commitment) research group at Complutense University of Madrid whose main aim is to understand how art and technology can have a positive impact on society.

Concha Herrero
Senior Lecturer at (UCM) Complutense University of Madrid
Faculty of Geological Science (UCM), Geodynamic,
Stratigraphy and Paleontology Department.
cherrero@geo.ucm.es

PhD in Paleontology, specialist in Micropaleontology, from the University Complutense of Madrid. Senior Lecturer at the Geodynamic, Stratigraphy and Paleontology Department of the Faculty of Geological Sciences (UCM) where she teaches Paleontology and Geological Mapping in the degrees in Geology and Geological Engineering, and Applied Micro-paleontology in the Master's Degree in Advance Paleontology. Her research focuses on Pliensbachian and Toarcian foraminiferal paleontology, and on Jurassic Boundary Strato-Types (GSSPs). She develops systematic, taphonomic, biostratigraphic, palaeoecological and palaeobiogeographical studies on Lower Jurassic foraminifera, emphasising biostratigraphy and identification of extinction and renewal of faunal events. She is pioneering in Jurassic taphonomic studies and in the application of quantitative methods and multivariate and she analysis in paleoecology and paleobiogeography of Lower Jurassic foraminifera in Spain. She has written books, book chapters and articles in national and international journals, and belongs to the Mesozoic Biotic Events Research Group (UCM) collaborating in DGI and IUGS Projects.

Universitat Oberta de Catalunya