

Educational Effects in the Implementation of a New Tool for Teaching Traditional Artistic Casting

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Abstract

This work proposes the incorporation of educational innovation into traditional artistic techniques. Specifically, a research seminar on artistic casting using conventional microwaves was carried out. The objective of the research was to analyze the feasibility of this implementation and evaluate its learning impact. Questionnaires were given to the participants before and after the experience to evaluate the knowledge obtained. Among other aspects, the questionnaires evaluated how innovation procedures can improve university art classes and vocational training oriented to art practices, and in particular artistic casting, which often presents problems in its delivery due to the technical complexities required to carry it out. Once the research was completed, it was concluded that the dissemination and knowledge of these traditional techniques can be expanded to more spaces, thanks to new learning methodologies. In addition, the innovation carried out improved the motivation of students to learn conventional artistic techniques.

Introduction

Historically, art has always been closely linked to technology, from the invention of writing, through the first techniques of image or sound representation, to the Bronze Age, as well as during the period of twentieth-century art movements and the post–World War II period, from which contemporary art emerged. However, there are problems with the curricular adaptation of arts teaching, from primary education to higher education, which are often based mainly on traditional methods (Rusell & Zembyllas, 2017). However, problems persist in adapting art curricula, from primary education to higher education, primarily due to significant misalignments between the content taught and the demands of the workplace. For example, artistic studies often rely primarily on traditional methods, without incorporating current or innovative approaches (Rusell & Zembyllas, 2017). Contemporary artistic expression, like many other areas of society, is permeated by technology, which promotes individual growth and encourages collaboration and engagement among peers (Geroimenko, 2020).

In the contemporary era, with the evolution of different technological means, the arts continue to expand the forms of expression and human interaction. Incorporating new technologies into the teaching of visual arts can open creative possibilities and encourage student engagement. It is inevitable for the advantages offered by the tools and technological progress, often embraced enthusiastically by artists, to be decisive for a broader creative process.

One of the great challenges of university centers is to demonstrate their relevance to society, being aware that the benefits of these centers are not limited to the training of their students, but also to the study and generation of innovation (Benneworth, 2013). On the other hand, technological advances in education encourage pedagogical practice connected to the numerous resources and possibilities of teaching and learning available. A reality marked by changes in different sectors of society drives new conceptions, paradigms, experiences, and ways of perceiving the world (Schlemmer et al., 2020). Some research shows that the use of technology is a useful aspect in preparing students for the twenty-first century. In other words, it increases confidence in learning and relieves the frustration of the art student (Lemon, 2015).

With the implementation of new technologies, such as microwave metal smelting, the creative process can be explored in a faster and more accessible way, leaving room for error (Lemon, 2015). The teaching of bronze casting is rarely applied in the curricula of the artistic disciplines because it involves some infrastructure and security restrictions, in addition to the high production costs. Microwave smelting (hereinafter abbreviated as MW) is a method of metal smelting that arises as an improvement in the execution processes within the scope of teaching and/or apprenticeship workshops.

This article presents the results of a case study that focuses on the incorporation of a new metal casting process in higher education, based on the principles of STEAM education—Science, Technology, Engineering, Arts and Mathematics—which emphasizes the development of critical thinking, problem-solving, collaboration, communication and creativity. The implementation of the STEAM approach in technical higher education, such as in the context of metal casting, faces challenges ranging from curricular rigidity and the need for interdisciplinary teacher training, to the limitations of technological and infrastructural resources. In addition, the cultural change required to integrate science, technology, engineering, arts, and mathematics collaboratively often meets resistance among students and teachers accustomed to traditional disciplinary structures. As the systematic review of STEAM in the last decade highlights, effective integration between areas depends not only on innovative methodologies, but also on institutional conditions that favor interdisciplinarity, creativity, and complex problem solving (Perignat & Katz-Buonincontro, 2019).

State of the Art

The use of technology in education has generated profound transformations in teaching and learning, especially in the field of arts education. Access to digital media, free software, cell phones, and other tools expands the expressive languages available to students and brings arts education closer to contemporary cultural practices. Art, as a field in constant transformation, requires students and teachers to possess technical mastery, aesthetic sensitivity, and critical capacity when faced with new means of cultural production and dissemination (Santaella, 2003). Based on international case studies at universities, art academies, and research centers, this article discusses how technologies—even simple or low-cost ones—can be integrated into artistic and pedagogical practices. The analysis highlights critical, sustainable, and interdisciplinary approaches in contexts that value experimentation, authorship, and contemporary thinking in the field of art.

The following examples illustrate efforts within European higher education that align with the objectives of this research. The Foundry Futures project (Central Saint Martins – University of the Arts London) rethinks artistic casting education through sustainable practices and accessible technologies. Students work with sand casting, lost-wax casting, metal recycling, and 3D printing to create molds, integrating artisanal and digital processes (UAL, 2025). The emphasis is on experimentation and the environmental impact of sculptural practice. At the Gerrit Rietveld Academie (Amsterdam), the use of artisanal and digital production technologies is encouraged in interdisciplinary projects. The metal studio, for example, teaches casting with simple materials (such as recycled aluminum), welding, and digital modeling. Students are encouraged to integrate sculpture, video, performance, and electronics (Knoller, 2019). The Bezalel Academy of Arts and Design (Israel) offers artistic casting

workshops focusing on the use of accessible materials and the dialogue between tradition and contemporaneity. In addition to practicing with gas ovens and wax molds, students develop projects in partnership with communities, including sound, video, and simple sensor technologies (Avrahami, 2018).

Throughout history, casting has been done in bronze due to its structural resistance and non-atmospheric corrosion, particularly after polishing, which can also result in an aesthetically desirable patina occurring (Albaladejo, 2006). The evolution of casting processes has been gradual, resulting in various methods for creating a sculpture. To carry out this process, it is essential to use refractory molds made from substances that can withstand extremely high temperatures without deteriorating, which are shaped according to the model to be produced.

The most commonly used technique is lost wax casting, which, as its name suggests, involves the loss of wax (i.e., the wax contained in the mold melts and is replaced by metal) (Krekeler, 1971). The research into the lost wax process using MW in artistic casting, more specifically the heating of the mold, was initiated by Albaladejo (2006), whose goal was to replace the furnace with a flame due to safety concerns arising from high CO₂ emission rates (Díaz-Alemán et al., 2019). Because of this, among other reasons, it is a teaching that is not taught in all sculpture itineraries, even though it is a historically important technique (Aguilar, 2000).

In order to contribute to the needs expressed above, microwaves emerged as part of this exploration of the lost wax process, and the use of the technological innovation of this new method was imminent in the thermal processing industry (Plaza, 2015). The properties of dielectric heating make the procedure more efficient and environmentally sustainable, as less time is required because more energy is directed to the area being treated (Menéndez and Moreno, 2017). Studies have shown a reduction in the necessary infrastructure, execution time and safety (Cárdenas et al., 2009). Therefore, MW technology can alleviate some of the previous concerns that some teachings may have regarding casting.

Technology needs to be at the service of creative, interactive, and personalized learning practices. More important than the technology itself is the pedagogical project that guides its use. Díaz (2024) emphasizes that technology is not an end in itself, but a means to expand teaching and learning possibilities. In the case of art education, this means that tools such as drawing apps, videos, digital photography, or online platforms are only transformative when integrated into a consistent pedagogical project that fosters student authorship, imagination, and critical thinking.

Focusing production on small formats contributes to the overall objective of the research line, which is to broaden the accessibility of metal casting education in educational centers.

Jewelry casting, one of the oldest techniques for producing adornments, has a rich and evolving history that dates back thousands of years. The lost-wax technique, in particular, has been known since the third century BCE. and is still used today to create unique and intricate pieces in jewelry.

Finding a concrete method of thermal processing for this area may be a reason for colleges to reconsider bronze casting in their syllabus, as MW method more easily complies with safety regulations and brings traditional techniques closer to current means such as new technologies, which improve student learning (Renau, M.L. 2016). But the appropriate use of this technology requires specialized study, which is why this seminar worked with interdisciplinary knowledge, such as the introduction of the knowledge of microwave engineering and the physicochemical processes inherent in casting, applied to the production of plastic arts. Such an approach favors the training that students receive by expanding their knowledge to other technical areas, in addition to contributing to their autonomy. Among other things, a 66 % reduction in the process is achieved thanks to the use of electromagnetic materials.¹

Contrary to the idea that innovation requires high technology, many experiences in higher education show that simple technologies can be effective for artistic education. These approaches prioritize materiality and process over the final product; student autonomy and authorship; critical reflection on the medium and its social, political, and environmental context; and transdisciplinarity, integrating art with science, technology, and digital culture. These practices are also aligned with Freire's (1970) critical pedagogy, which proposes the student as an active subject in the construction of knowledge, and with the principles of maker culture, which value practice, error, and experimentation as legitimate forms of learning.

Artistic higher education has benefited from a more flexible and critical approach to the use of technologies, evidenced by international projects that combine technical tradition, sustainability, accessibility, and innovation. These experiences demonstrate that technology, when considered as a language and means of expression, contributes not only to students' technical training but also to their ability to intervene in the world with sensitivity and critical

¹ The rapid polarization and depolarization of the mold exposed to electromagnetic radiation (MW) generates instantaneous heat, resulting in volumetric heating. The electromagnetic field interacts with the entire volume of the object, unlike a conventional furnace, where heat is produced only from the outside in (Cárdenas et al., 2009). These advantages make this energy source an ideal candidate for a sustainable and low-cost heat treatment. Irradiation does not cause combustion of the wax, improving handling, recovery and process control, since heat transmission does not generate residues typical of combustion techniques, such as CO₂, CO₂ and derivatives.

awareness.

Research Setting

The sculpture department of the Faculty of Fine Arts of the University of Lisbon has eight sculpture laboratories with an emphasis on ceramics, wood, unmelted metal, medals, stone, plastic, plaster, and conservation and restoration. Each student chooses a laboratory to specialize in, that is, they develop the five learning levels of this curricular unit during the degree. This choice allows for the progressive development of the five learning levels of the curricular unit, ensuring educational coherence and skill consolidation. By focusing on a single laboratory, students not only acquire more specialized technical and creative knowledge but also strengthen their autonomy and responsibility in the educational process. Furthermore, this dynamic contributes to the construction of a unique professional identity, enabling students to combine their personal interests with academic demands and plan a future field of activity from their initial training. However, during their undergraduate degree, students can also choose to attend specific levels of other laboratories, thus expanding their educational repertoire. This opportunity aims to provide exposure to different subjects, formalities, and processes, allowing students a more diverse and interdisciplinary experience. The openness to exploring stages in other laboratories enriches the overall training, fostering both transversality of knowledge and experimentation with diverse languages. Thus, the curricular structure balances specialization—ensured by continuous progression in a leading laboratory—with the flexibility necessary to stimulate curiosity, creativity, and the ability to engage in dialogue between distinct areas of artistic and pedagogical knowledge.

All laboratories are equipped with machinery and tools necessary for practical classes. Before the Bologna Reform (European university superior education reform), when the degree program lasted five years, the metals course included a brief workshop on lost-wax bronze casting. However, the current curriculum lacks the time or resources for this type of experimentation. In this sense, the present case study demonstrates the potential of this method in the specific context of university education, where MW casting can be adapted by the contemporary artist for the production casting. By conducting this educational experience with the implementation of this process, new possibilities have opened up in the field of pedagogy in artistic foundry, such as the replacement of traditional furnaces, the significant reduction of processing time, the reduction of energy consumption and the possibility of reproducing the learned technique without a specialized workshop when students finish the course.

Methodology

The introduction of this procedure in higher education not only broadens the tools available

for artistic practice, but also offers an affordable, safe and efficient alternative to conventional casting methods. In addition, the significant reduction in processing time contributes to a more effective use of resources and teaching time, encouraging experimentation, autonomy and sustainability in artistic making. The approach can thus transform not only the practice of the individual artist, but also the very models of teaching the visual and sculptural arts in higher education.

The case study had the participation of eleven students enrolled in FBAUL (Faculty of Fine Arts of the University of Lisbon), eight enrolled in the Sculpture Degree, two in the Sculpture Master's Degree and one in the Glass and Ceramics Master's Degree. The methodology applied involved the realization of a seminar that integrated transversal knowledge, offering students the opportunity to develop their opinions through a questionnaire that was administered to the participants in order to analyze the sample and the interests of the participants.

Instruments of Analysis and Sample

The training began with the presentation of the theme, the planning of the activities, and technical information about the art, foundry and microwave technology. Subsequently, a first questionnaire was distributed to analyze the sample and the interests of the participants.

A second questionnaire assessed the students' knowledge after their training with the innovative technique developed. The results of the questionnaires made it possible to compare previous and acquired knowledge of this technology crossover, as well as the methodology applied. The surveys were also aimed at establishing parameters that facilitate the incorporation of new technologies in subjects, as well as the importance of innovation in the learning of traditional artistic techniques.

The theoretical and practical contents of the seminar were taught over five days, lasting six hours a day. During the first two sessions, the necessary parameters for the creation of the wax models were established as a practice of artistic creation. That is, the students freely modeled shapes in casting wax. The activities began with several demonstrations using simple wax models, allowing students to visualize the processes in which they would be involved. Some enjoyed the experience and continued with independent hours, expressing themselves freely and without limitations. The subsequent sessions were dedicated to mold making, thermal processing, data collection, metal casting, surface finishing of the pieces and answering the final questionnaires, which evaluated the students' knowledge after the training.

The questionnaires were carried out according to the Likert scale, where the results allowed comparing the previous and acquired knowledge about this intersection of technologies, as

well as the methodology applied. The questionnaires also aimed to establish parameters that would facilitate the incorporation of new technologies in the disciplines, as well as the importance of transversal knowledge such as modeling. This methodology is suitable for capturing levels of agreement, satisfaction, or frequency with different statements, as it organizes responses into gradients (e.g., from “strongly disagree” to “strongly agree”). Using the Likert scale allows subjective perceptions to be transformed into quantifiable data, which facilitates both statistical interpretation and comparisons between different groups or research moments. Furthermore, this tool allows for the identification of trends, response patterns, and potential discrepancies, providing a solid basis for discussing the impact of pedagogical practices and student engagement in the educational process. According to Chyung, Roberts, Swanson, and Hankinson (2017), the proper application of the Likert scale requires attention to aspects such as defining the number of points and the inclusion (or not) of a neutral point. Such decisions directly influence the quality of the data obtained and the accuracy of possible interpretations, reinforcing the importance of a questionnaire design based on sound methodological criteria.

Innovation Processes

Modeling tools were used to create models, and gas torches for welding. In addition to making models directly in wax, indirect molds (silicone, plaster and alginate) were used as a creative resource, and even organic elements such as vegetables.

The drying and dewaxing stage included the MW procedure, with the students themselves applying the MW time/power curves² to their molds. In this way, the students internalize and appreciate the possibility of combining new technologies with traditional processes, revealing that these are permeable to the study of materials and traditional sculptural processes. Students are confronted with the complexity and delicacy of removing wax from its form (or mold). Since this operation requires a temperature application adapted to the conditions of each mold, as we had six, the difficulty lay in using the correct MW program and thus designing a gradual and controlled heating protocol without damaging the mold. Throughout this process students are highly motivated to achieve the goal of obtaining their elaborate wax creation in metal and assume the risks inherent to any casting.

² Once the compound's structure has been synthesized, it becomes suitable for receiving the metal casting. At this stage, the transparent material increases in temperature and regains its dielectric properties. The microwave absorption range at this point is between 400 °C and 500 °C. The electromagnetic element (susceptor) absorbs microwave energy stably at temperatures between 25 °C and 450 °C, transferring this energy to the ceramic solid, which will only resume absorbing energy at higher temperatures.

For the second part of the sinter stage, the mold is introduced into the electromagnetic muffle for MW. This “sarcophagus” has the shape of two semi-cylindrical beds facing each other (see Figure 1A, B and C). In this part of the seminar, the students have put into use all the materials and technological innovation resources and are in the process of learning transversal skills.



Figure 1. (1A), Electromagnetic muffle for MW firing. (1B), Firing of the refractory mold. (1C), Casting of the seminar student mold (Images by Noah Perez)

Once the refractory paste is sintered, mold is suitable for casting, safeguarding the efficiency and safety of the process. The students are present at the casting, gaining unique experiences and facing contingency and problem-solving aspects that do not take place in original method or theoretical seminars. Once the casting is finished, after releasing the model from the mold, the metal is worked up to the surface finish using cutting, beating, sanding, patina and polishing techniques. As can be seen in the following figures (see Figures 2A and B), the results obtained in metal are faithful to the original wax models, serving as accreditation of the innovation technique.



Figure 2. (2A), Wax tree model set. (2B), metal tree model compared (Images by Beatriz Aboim)

Table 1 (below) briefly compares the conventional method versus the experimental method.

Table 1

Procedural comparison of the original method versus the microwave method

Procedure	<i>Conventional thermal process</i>	<i>Microwave thermal process</i>
Fabrication of the mold surrounding the wax model.	A metal cylinder is used as formwork.	A two-valve cylinder, removable with PVC, is used.
The mixture is made with 38 to 40% water, with a mixer and a vacuum pump.	Recommended drying time is 1 to 4 hours, depending on size.	In this investigation the waiting time was 2 hours.
Start of thermal process: Dewaxing.	It is placed in the electric furnace for 8 hours, normally 50% of the wax is collected.	It is introduced in MW on the collecting tray, and after 45 min of exposure, the tray is removed and the PVC is introduced into the hot mold in the MW muffle.
End of the process: Cooking.	Does not require handling until 8 hours.	The muffle is introduced into the MW and 2 hours of firing is applied.
Casting of the molten metal into the mold.	Opening the oven and removing the mold.	The MW furnace is opened, the MW muffle is removed by opening only the upper shell.

Questionnaires

Once the information was collected, the items were contrasted by cross-checking data between the questionnaires [A-D]. Item (1A) shows (Table 5) that there is an audience in the studied context that is interested in smelting topics. Item (2A) reveals the impact and fulfillment of the objectives. Item (3D) reveals that the seminar allowed students to cultivate their own scientific criteria and their direct relationship with the creative process. Item (4D) reveals the result of the seminar methodology as acquired data for typified use. In item (5D), the autonomy and self-confidence that the knowledge of a new technological application for the foundry has developed in the students was revealed. The idea of the advantages of the use of MW, oriented to the comparatively shorter time, emerges. Added to the accessibility of the infrastructure, it reinforces the students' interest in generating metal work. This, in turn, generates capacity and autonomy to handle assembly and space ratio issues, considering the typical density of the subject treated, due to the possibility of using furnaces as common as MW. Item (6D) reveals the understanding and point of view of the sample on MW applications in processes other than casting, as well as the benefits of associating its implementation to artistic production. Some examples could be the use of MW for drying plasters or sintering of glass and ceramics. Item (7D) analyzes whether there is a desire to go beyond the learning environment to one of experimentation and research, which would argue for the need to house more technological spaces in fine arts techniques.

Discussion

At the university level, of the sixteen faculties that offer theoretical and practical studies on cast bronze sculpture (in Spain, Portugal, and Italy, faculties where workshops were developed previous to this research), no faculty has officially incorporated microwave technology as an improvement procedure. Nevertheless, as mentioned before, MW is found in a multitude of establishments related to thermal processes, a result that allows us to affirm that the social advantages are not yet reflected in the education of this discipline.

From the first questionnaire [A and D] (Tables 3 and 4), it was possible to analyze the starting conditions, determine the knowledge acquired, and thus confirm the transformation, leading to unified statements. Table 5 presents the percentage levels of this data.

The comparison of the questionnaire [A-D] shows that, although the participants are interested in new technologies (2.3, 3.8 and 5 out of 5, questionnaire A), none of them had had previous experience or knowledge of artistic casting, given that the response does not exceed 2 points out of 5 in the questionnaire [D] (table 4). The contrast between questionnaires [A-D] allows us to affirm a positive impact on student demand. On the other hand, it was observed that the students had high prior knowledge of the use and operation of MW (4.7 and 5 out of 5,

questionnaire A). It appears that crossing technologies has favored the learning of artistic casting, since, according to questionnaire [A], just a small part of the sample had previous knowledge of the operation of casting. According to questionnaire [D], the students found it easy to learn artistic casting, and they also found it equally easy and dynamic to apply the common knowledge to other areas such as those covered in the seminar, since (3.8 and 4 out of 5) of the sample rated it as such in questionnaire [D].

In the search for results adapted to the specific possibilities, the participants were offered a space to report their experiences in more detail through written texts. One student wanted to highlight the following: “During this work the failures of equipment or materials and through new experimentation and analysis were solved. Theory and practice were very combined at all times; this led to a much deeper knowledge than just reading or listening about the subject” (Workshop student). This student’s evaluation indicated: “Very good. Very practical, with great interaction between trainers and students, with concrete development and search for solutions for the different phases that involved the whole group in a very active way. Quite explicit and objective” (Workshop student).

During the wax manufacturing sessions, students were able to create their sculptures as well as make their own refractory mold. The participants developed reasoning systems that allowed them to connect with ceramics, casting, printing techniques, and molding. This allowed them to deepen their knowledge of ceramic processes intrinsic to casting, such as the application of heating and the structural change of sintering. The problems related to imitating heat treatment with MW technology allowed the students to get involved in the process in a more attentive way than in a traditional firing.

By directly observing the physical and thermal transformations of the mold, students gain a deeper understanding of the casting process. The microwave method’s two-stage heating and reduced processing time make this possible within a single session, whereas the conventional technique requires approximately eight hours and must be scheduled outside of class time. As a result, students no longer encounter molds that have already been pre-fired before the session begins, but instead actively participate in the entire process.



Figure 3. Casting of the pieces (Image by Leonor Rodrigues).

Table 2

Data collected by the participants in the forms distributed to collect technical data during the production process.

Author	Wax collected (%)	Loss in mass due to drying (%)	Title of the piece	Casting quality
Ângela and João	89	18	<i>morangos</i>	<i>high</i>
Andreia and Beatriz	98	10	<i>olhos</i>	<i>high</i>
Carlos and Ricardo	90	21	<i>ovo ramificado</i> <i>patas</i>	<i>high</i>
Vera and Maria	86	13	<i>caracóis</i> <i>motivos vegetais</i>	<i>medium</i>
Noah	99	15	<i>tabla de surf</i>	<i>high</i>
Romeu and Pedro	89	16	<i>cogumelos</i>	<i>high</i>

From the observation and questionnaires, it is possible to assess the students' high motivation for learning. The students were involved in the MW seminar and its use to solve the thermal problems inherent in any casting. The results of the sculptures were positive. As shown in Table 2, the performance of the dewaxing stage is remarkable, where 92% of the wax was recovered. Similarly, the quality of the molds was not affected, since the photographic comparison showed that the metallic product obtained was faithful to the primitive models.

These results demonstrate versatility of operation in random shapes such as those created by the students and, therefore, the suitability of the technique for teaching. The following table (3) shows the results of the questionnaires carried out before starting the activity (A):

Table 3*Questionnaire (A) before the start of the seminar*

Ask	Result (1-5)
I have made a foundry sculpture before.	1
I have used wax to model sculptures.	1.2
I know how metal melting furnaces work or have seen one in operation.	1
I know and have worked artistic figures with bronze.	1
I know the process of artistic microcasting with refractory linings for jewelry.	1
I have used a domestic microwave before	5
I know how a domestic microwave works	4.7
I have used microwave programs before	2.2
I have a good knowledge of microwave operation	1.8
I am interested in working in the field of sculpture.	5
I am interested in working in the field of artistic casting.	2.3
I am interested in working with new technologies	3.8

Table 4*Questionnaire [D] after completion of the seminar*

Ask	Result (1-5)
I was able to complete the entire activity without major problems	4.6
I found it easy and dynamic to carry out the intrinsic transversal knowledge in the seminar.	3.4
I found it easy to handle the wax	2.8
I have found it easy to learn artistic casting	4
I found it easy to use the microwave	3.6
I found the use of the microwave very interesting.	4
I think it is important to introduce new technologies in artistic creation.	4
I think it is important to include microwave technologies in sculpture courses.	5
I believe that the use of new technologies allows me to broaden my accessibility in sculptural creation.	5
I intend to continue using new technologies for my artistic creations.	3.4
I find it interesting to be able to merge traditional techniques such as artistic casting and microwaves.	5
I would like to have a course that offers new technologies.	3.4

Table 5*Percentage value of responses [A-D]*

	Ask	Reply
1A	Previous level of relationship with casting techniques	B - some, in about 72.7% of the responses (eight); C - very much, as an amateur, in about 27% of the answers (three);
2A	Information about the technology crossover " <i>Microwaves and sculpture casting</i> . Before attending the Seminar	A - none, in about 54.5% of the responses (six); B - some, in about 45.5% of the responses (five);
3D	How do you value the importance of research processes in this workshop, either in the development of the artistic creative process or in the review and updating of technological casting processes?	C - very much, about 100 % of the responses (eleven);
4D	How do you rate your learning on research methodology and analysis of results in the seminar?	B - some, in about 36.4% of the responses (four); C - very much, in about 63.6% of the responses (seven);
5D	Ability acquired to apply the knowledge provided in the workshop in your future autonomous artistic practice of metal casting?	B - some, in about 45.5% of the responses (five); C - very much, in about 54.5% of the responses (six);
6D	Curiosity for further research on the application of Microwave technology to artistic production processes in fine arts?	B - some, in about 81.8% of the responses (ten); C - very much, in about 18.19% of the responses (one);
7D	Willingness to attend other workshops on microwave and foundry technology?	B - some, in about 36.4% of the responses (three); C - very much, about 63, 6 % of the answers (seven);



Figures 4, 5, 6. Model in wax compared to the one obtained in metal (Images by João Pereira).



Figure 7. Final metal models (Image by Beatriz Aboim).

Conclusion

This paper has explored the implementation of microwave (MW) technology for teaching artistic casting and found it to be both promising and viable due to its low-cost, safe, and environmentally friendly methodology. This increases the accessibility of traditional techniques in classroom-workshop teaching. This seminar made it possible to train students in casting processes and technical research, delving into the fundamentals of casting and the operation of heating technologies. The results demonstrated that the casting process decreased its duration in the classroom from 8 to 3 hours of treatment, improving training efficiency compared to the traditional procedure.

It is concluded that the contribution to the students' autonomy is high. MW operation involves challenges of transversal teaching, which, in turn, enables students to solve problems that require the handling of new technical areas, a necessary reality both in research and in the professional field.

This seminar shows that the microfusion technique using MW is completely viable. Furthermore, the seminar allowed the students to acquire knowledge about the handling of waxes, casting processes and molten metal work within a faculty where metal casting is not otherwise taught. Looking ahead, it is proposed to integrate this content into official university courses.

References

- Aguilar Galea, J. A. (2000). *La enseñanza de la fundición artística en las facultades de Bellas Artes Españolas* [The teaching of artistic casting in Spanish Faculties of Fine Arts] [PhD thesis, Universidad de Sevilla]. Depósito de Investigación Universidad de Sevilla. <https://idus.us.es/handle/11441/92168>
- Albaladejo, J. C. G., & González, I. R. (2006). *Fundición a la cera perdida: Cellini y la magnetite* [Lost-wax casting: Cellini and the use of magnetite]. *Bellas Artes: Revista de artes plásticas, estética, diseño e imagen*, (4), 13-28. <https://doi.org/10.25145/j.bartes>
- Avrahami, Y. (2018). Community-based artistic foundry projects in Israel: Bridging tradition and technology. *International Journal of Education through Art*, 14(3), 305–320.
- Benavente Martínez, R. (2015). *Desarrollo de Materiales Cerámicos Avanzados con Altas Prestaciones Mediante Técnicas no Convencionales de Sinterización: Microondas* [Development of Advanced High-Performance Ceramic Materials Using Non-Conventional Sintering Techniques: Microwaves]. [PhD thesis, Universitat Politècnica de València]. Repositorio Institucional UPV. <https://doi.org/10.4995/Thesis/10251/49358>
- Benneworth, P., Charles, D., Hodgson, C., & Humphrey, L. (2012). *The relationship of community engagement with universities' core missions. University Engagement with Socially Excluded Communities* (pp. 85–101). Springer, Dordrecht. https://doi.org/10.1007/978-94-007-4875-0_5
- Cárdenas, C., Restrepo, R., García-Sucerquia, J., Marin, J., García, C., (2009). *Las microondas como una alternativa para el secado de materiales cerámicos tradicionales* [Microwaves as an Alternative for the Drying of Traditional Ceramic Materials]. *Revista Latinoamericana de Metalurgia y Materiales (RLMM)*. (29), 427-432.
- Chyung, S. Y., Roberts, K., Swanson, I., & Hankinson, A. (2017). Evidence-based survey design: The use of a midpoint on the Likert scale. *Performance Improvement*, 56(10), 15–23. <https://doi.org/10.1002/pfi.21727>
- Clark, D. E., Sutton, W. H. & Lewis, D. A. (Eds.). (1997). *Microwaves: Theory and Application in Materials Processing IV*. American Ceramic Society.
- Díaz-Alemán M, D (2024). *Imágenes generadas por computadora para el diseño de concepto en arte contemporáneo. Discurso, materia y contextos: volver a pensar las artes* [Computer-Generated Images for Concept Design in Contemporary Art. Discourse, Matter, and Contexts: Rethinking the Arts] (pp. 95-108). Tirant lo Blanch.

- Díaz-Alemán, M., Meier, C., Pérez-Conesa, I., & Saorin, J. (2019). Fundición artística de objetos complejos impresos en 3D con PLA (ácido poliláctico) como alternativa al modelo de cera [Artistic Casting of Complex 3D-Printed Objects in PLA (Polylactic Acid) as an Alternative to the Wax Model]. *Arte, individuo y sociedad*, vol. 31(3), 543-556. <https://doi.org/10.5209/aris.60906>
- Geroimenko, V. (2020) (Ed.). *Augmented reality in education: A new technology for teaching and learning*. Cairo: Faculty of Informatics and Computer Science. <https://doi.org/10.1007/978-3-030-42156-4>
- Groover, M. P. (2007). *Fundamentos de manufactura moderna: materiales, procesos y sistemas* [Fundamentals of Modern Manufacturing: Materials, Processes, and Systems]. McGraw-Hill Interamericana de España S. L.
- Jayavabushana, S. K. & Venkatesh (2020). Analysis of microwave dewaxing and its advantages over conventional autoclave dewaxing-A review. *European Journal of Molecular & Clinical Medicine*, 7(1):1668–1672.
- Knoller, N. (2019). Creative coding in schools: Integrating art and computer science. *Media Arts Journal*, 12 (2), 45–59.
- Krekeler, K. “A”. (1971). *Microfusión. Fundición con modelo perdido* [Microcasting: Lost-Pattern Casting]. Gustavo Gili.
- Lemon, N. (Ed.) (2015). *Revolutionizing arts education in K-12 classrooms through technological integration*. La Trobe University. <https://doi.org/10.4018/978-1-4666-8271-9>
- Menéndez, J.A., Moreno, A.H. (2017). *Aplicaciones industriales del calentamiento con energía microondas* [Industrial Applications of Microwave Heating]. Editorial Universidad Técnica de Cotopaxi.
- Moreno, F. (2022). *Procesado térmico de moldes refractarios para fundición artística mediante tecnología microondas* [Thermal Processing of Refractory Molds for Artistic Casting Using Microwave Technology]. Universidad de La Laguna.
- Perignat, E., & Katz-Buonincontro, J. (2019). A systematic literature review of STEAM education in the last decade. *Journal of STEAM Education and Research*, 2(1), 1–16. <https://doi.org/10.1177/2158244019841601>
- Plaza, P. J. G. (2015). *Control de la temperatura en sistemas de calentamiento por microondas* [Temperature Control in Microwave Heating Systems]. [unpublished PhD thesis]. Universitat Politècnica de Valencia. <https://doi.org/10.4995/Thesis/10251/61475>
- Renau, M. (2016). A review of the traditional and current language teaching methods.

International Journal of Innovation and Research in Educational Sciences, 3(2).

Rusell, J., & Zembylas, M. (2022). Arts integration in the curriculum: a review of research and implications for teaching and learning. In L. Bresler (Ed.), *International Handbook of Research in Arts Education, Part 1*. Springer Dordrecht.
<https://doi.org/10.1007/978-1-4020-3052-9>

Santaella, L. (2003). *Posthuman cultures and arts: From media culture to cyberculture*. Paulus.

Schlemmer, E., Di Felice, M., Serra, I. (2020). Educação OnLIFE: A dimensão ecológica das arquitetura digitais de aprendizagem [OnLIFE Education: The Ecological Dimension of Digital Learning Architectures]. *Educar em Revista*, (36).
<https://doi.org/10.1590/0104-4060.76120>

University of the Arts London (2025). *Foundry futures: Reimagining sustainable casting in art education*. <https://www.arts.ac.uk>

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