

IGNITING INNOVATION THROUGH EDUCATION: CERAMICS HIGHER EDUCATION AS A STRATEGIC DRIVER FOR INDUSTRIAL TRANSFORMATION

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ABSTRACT

The ceramics industry is facing a watershed moment. Energy transition, digitalisation, sustainability, surface functionalisation, research into new materials and the development of digital decoration are profoundly transforming the sector. In this context, innovation cannot rely solely on the incorporation of new technologies or on the modernisation of production processes: it requires professionals capable of understanding, interpreting and transforming these tools, drawing on a solid, comprehensive and specialised education.

The *Escola Superior de Ceràmica de l'Alcora* (ESCAL) is a unique model of higher education in ceramics. Its current curriculum is configured as an Advanced Degree in Plastic Arts specialising in Ceramics, structured along two pathways – Science & Technology and Art & Design – which reflect the discipline's dual material and creative dimensions. Furthermore, Law 1/2024 on Higher Arts Education reinforces the academic recognition of these courses by integrating them into Level 2 of the Spanish Qualifications Framework for Higher Education (MECES), on a par with equivalent university degrees.

This article argues that higher education in ceramics must occupy a central place in any future strategy for the sector. The competitiveness of the ceramics sector will not depend solely on higher production levels but on providing better training; not just on incorporating technology but on generating knowledge; not only on preserving a tradition but on transforming it into innovation.

1. INTRODUCTION: Lighting the way for the future of ceramics

A conference called IGNITE inevitably invites discussion about fire, and few disciplines can do so with as much legitimacy as ceramics. Ceramics is based on a fundamental transformation: matter subjected to fire, clay transformed into an object, the surface altered by temperature, and human knowledge embedded in a material capable of withstanding the test of time.

But today, the fire that ceramics requires is not just that of kilns. It is also the fire of knowledge, innovation, research, creativity and training. The ceramics sector is facing a new phase in which it is no longer enough simply to produce well: we have to think better, design better, research better and train better.

The province of Castellón is a region where ceramics represent industry, culture, employment, history, identity and the future. However, precisely because of its strategic importance, the sector cannot afford to tackle the challenges of the 21st century with inadequate training resources. The digitalisation of processes, environmental sustainability, energy efficiency, digital decoration, the functionalisation of surfaces, product customisation and international competition all demand increasingly well-rounded professional profiles.

The fundamental question is not merely what kind of ceramics we will manufacture in the future. The truly decisive question is who will be able to conceive, develop, produce, communicate and transform ceramics. This is where higher education plays a key role. Without qualified technicians, technology becomes an underutilised tool. Without designers who understand the material, the surface loses its depth. Without scientific knowledge, innovation is reduced to trial and error. Without applied research, the sector loses its anticipatory capability. Therefore, the thesis of this article is clear: there can be no innovation without education.

This need for education should not be seen as an abstract concept, but as a practical prerequisite for sustaining the sector's development. The ceramics industry works with increasingly precise processes, ever more sophisticated materials and more demanding markets. In this context, competitive advantage does not stem solely from having the technology, but from having professionals capable of interpreting it, adapting it and turning it into real solutions for business, society and the region.

2. CERAMICS: A complex discipline facing new challenges

Ceramics is one of humankind's oldest technologies, but it would be a mistake to view it as a field of the past. Few disciplines demonstrate so clearly the continuity between tradition and innovation. From the earliest vessels to contemporary architectural surfaces, from artistic ceramics to advanced technical materials, from hand-painted decoration to digital printing, ceramics has always been a transformative technology.

This breadth poses an obvious challenge: training professionals in ceramics requires much more than simply teaching a specific technique. Ceramics demands an understanding of raw materials, formulation, thermal behaviour, surface, colour, glaze, texture, industrial process, image, design, functionality and context of use.

A glaze is not merely a shiny layer on a workpiece. It is a chemical composition, a suspension, a surface, a thermal response, an interaction with the substrate and a visual experience. A ceramic tile is not just an industrial product. It is the result of design decisions, materials research, and processes involving pressing, drying, firing, decoration, dimensional control,

mechanical strength, colour management and market positioning. Artware is not just an expressive form: it also involves knowledge of the material, fire control, visual culture, technique and experimentation.

For this reason, the future of ceramics cannot be built on fragmented visions. The sector needs professionals capable of integrating different areas of expertise and engaging in dialogue with a laboratory, a design department, a production line, a technology company, an art studio or a research centre.

The complexity of ceramics is precisely evident in this connection between different scales. A seemingly minor decision – such as modifying a raw material, a change in milling, modifying the firing curve or alteration in the applied glaze – can have consequences for the product's aesthetics, strength, dimensional stability, durability or industrial feasibility. Training professionals capable of understanding these relationships is essential for reducing errors, improving processes and opening up new possibilities for innovation.

3. REGULATED HIGHER EDUCATION AND THE ACADEMIC FRAMEWORK

The ceramics industry has historically grown thanks to a combination of experience, professional skill, entrepreneurial spirit, technological innovation and the transfer of knowledge within companies themselves. This industrial culture has been one of the sector's great strengths. However, today's challenges require us to go one step further: experience remains essential, but it is no longer sufficient on its own.

Formal higher education provides structure, rigour and recognition. It enables knowledge to be organised, skills to be established, theory and practice to be integrated, research to be incorporated, academic progress to be assured, and provides the sector with professionals of proven calibre. It is not a question of replacing on-the-job learning, but of reinforcing it; it is not a question of pitting higher education against industry, but of connecting the two together.

At ESCAL, the current curriculum corresponds to an Advanced Degree in Plastic Arts specialising in Ceramics, structured along two pathways – Science & Technology and Art & Design – which reflect the discipline's dual material and creative dimensions. This arrangement allows for specialised training tailored to students' interests and the professional profiles required by the sector, whilst maintaining a comprehensive common foundation.

The framework for these courses is set out in Royal Decree 634/2010 of 14 May, which regulates the core content of higher education in visual arts at bachelor's degree level within the specialist fields of Ceramics and Glass. This Royal Decree defines the purpose of these courses as the provision of qualified training for professionals with artistic, scientific, technological, pedagogical, research and creative skills applied to industrial and artistic innovation. It also defines the professional profile for a specialist in Ceramics as that of a professional capable of understanding, identifying and resolving formal, functional, technical, production-related and socio-economic problems, whilst adapting to developments in technological, industrial, aesthetic and socio-cultural processes.

This framework is supplemented by Law 1/2024 of 7 June, which regulates Higher Arts education. The law reinforces academic recognition of these courses within the higher education system and establishes their integration into the Spanish Qualifications Framework for Higher Education (MECES). Higher Arts courses are classified at Level 2 of the MECES, the same as equivalent university bachelor's degrees, whilst master's degrees in Arts are classified

at Level 3. This equivalence is essential for recognising the academic, professional and social value of the training provided at institutions such as ESCAL.

MECES recognition is not merely an administrative matter. It means setting these courses in their rightful place within the academic landscape and reinforcing their legitimacy in the eyes of students, families, businesses and institutions. For a sector that needs to attract talent, this recognition is crucial: it makes it clear that studying Ceramics at ESCAL is not a matter of choosing a peripheral course, but rather gaining access to specialised higher education, equivalent in level to university degrees and geared towards a professional field of high technical and creative complexity.

Furthermore, the profile defined by the regulatory framework is particularly well-suited to the contemporary reality of ceramics. The need to resolve formal, functional, technical, production-related and socio-economic problems clearly encapsulates the nature of the modern Ceramics profession. The future curriculum must build on this foundation to expand content in regard to digitalisation, sustainability, new materials, advanced design, applied research and knowledge transfer to the sector.

4. ESCAL: Uniqueness, region and holistic education

The *Escola Superior de Ceràmica de l'Alcora* (ESCAL) occupies a unique position within the European academic and professional landscape. Its significance lies not only in being a centre of higher education, but also in placing ceramics at the very heart of its educational programme. In many educational programmes, ceramics is integrated within broader studies in design, fine arts, applied arts or materials engineering. Whilst this presence is valuable, it is not the same as offering a higher education qualification focused exclusively on Ceramics as a complete field of knowledge.

ESCAL's location in l'Alcora further reinforces such singularity. The school is located in a region where ceramics forms part of its history, economy and culture. The classroom is not disconnected from the local region: industry, heritage, innovation and tradition co-exist on a daily basis. The school thus becomes a bridge linking past and future, between academic knowledge and the realities of production.

One of the key strengths of this model is its holistic approach. Ceramics is not taught as a collection of isolated techniques, but as a system of knowledge in which each dimension influences the others. The technical dimension provides an understanding of raw materials, clays, glazes, frits, pigments, kilns, thermal cycles, forming, firing, decoration, quality control and defect analysis. The scientific dimension brings rigour to the study of thermal behaviour, vitreous and crystalline structures, expansion, porosity, strength, absorption, colorimetry and compatibility between materials.

The artistic dimension connects ceramics with its expressive potential, as a medium for memory, a visual language, a symbolic tool and a field for contemporary experimentation. The design dimension explores the relationship between product, user, market, space and communication. Finally, the technological dimension links all of the above through digitalisation, printing, inkjet decoration, software, materials analysis, automated processes and new methods of surface development. ESCAL's strength lies not in choosing between these dimensions, but in integrating them.

This integration of dimensions has a direct impact on employability and adaptability. Students do not merely acquire isolated knowledge: rather, they learn to connect it. This ability to make connections is particularly valuable in companies where problems rarely fall within a single area. A surface defect may require chemical analysis, a review of the process, a design decision and commercial assessment. A comprehensive education programme enables students to operate in these intermediate spaces, where many of the real innovations take place.

5. INKJET TECHNOLOGY AND CERAMIC SURFACE

Inkjet printing technology is one of the best examples of why the sector needs specialised higher education. Its introduction profoundly transformed the ceramics industry, changing the way surfaces are designed, decorated, produced and understood. Digital decoration did not simply involve replacing one tool with another: it changed the language of the ceramic product, increased graphic resolution, facilitated customisation and linked digital design more directly to the industrial process.

However, inkjet printing cannot be understood solely as a printing technology. In ceramics, printing involves working with ceramic inks, glazes, substrates, absorption, firing, colour stability, colour management, material behaviour, resolution, layers, textures and technical compatibility. For this reason, training in inkjet printing requires a cross-disciplinary approach: students must understand both the graphic and material aspects; they must know how to design an image but also understand how it will transform in the kiln.

The ceramic surface has likewise broadened its significance. It is no longer merely about decoration, colour, gloss or texture. Today, it can be communicative, tactile, protective, technical, functional or experimental. It can provide visual value, but also specific functional properties. It can serve as a substrate for imagery, but also as a space for materials research. This development means that teaching must go beyond simply decorating surfaces to include understanding, designing, modifying and functionalising them.

The introduction of inkjet printing has also changed the way we think about ceramic design. An image is no longer conceived solely as an ornamental motif, but as information that must be translated into a material system subjected to firing. Colour management, resolution, the relationship with relief, the body and the glaze, or the superimposition of functional layers all require knowledge that combines visual sensitivity and technological understanding. This is one of the reasons why higher education must incorporate digital decoration not as an isolated tool, but as a cross-disciplinary field of study.

6. TWO MASTER'S DEGREES FOR TWO PATHWAYS TO THE FUTURE

The consolidation of two specific official master's degrees in Ceramics will strengthen ESCAL's role as a centre for advanced specialisation. Whilst the bachelor's degree provides a comprehensive foundation, the master's degrees will enable students to explore strategic areas for the sector's future in greater depth and address the two main strands of contemporary ceramics: technical and scientific innovation, and artistic, pictorial and design innovation.

The official master's degree in 'Digital Applications for the Functionalisation of Ceramic Surfaces' directly addresses the major technical and scientific challenges facing the ceramics sector of the future. Its focus lies at the intersection of innovation, digitalisation and materials.

Surface functionalisation enables the development of new properties relating to strength, cleanability, interaction with light, texture, protection, technical performance, sustainability and the incorporation of new characteristics. This master's programme consolidates training in digital applications, surface development, applied research, new materials, functionalisation processes and technology transfer.

The official master's degree in 'Pictorial Expressions in Contemporary Artistic Ceramics' complements this model from the artistic and design perspective. It integrates the traditional knowledge of pictorial ceramics with contemporary artistic expressions and emerging technologies applied to ceramic surfaces. Its significance lies in recognising that pictorial tradition is not a relic of the past but a living tool for artistic research. Both master's programmes demonstrate that ceramics must advance simultaneously towards science and art, towards technology and culture, and towards industry and creation.

The existence of these two master's degrees will enable the development of a coherent educational pathway. The Advanced Degree provides a broad foundation upon which students can understand Ceramics in terms of its material, technical and expressive complexity; the master's degrees, on the other hand, will allow for in-depth study in strategic areas. One programme directs Ceramics towards technical and scientific research into surfaces and materials, the other towards pictorial expression, contemporary creation and the renewal of artistic languages. This dual approach avoids a narrow view of innovation and demonstrates that Ceramics advances both from the laboratory and the studio, and from the factory and the workshop.

7. COMPETING FOR KNOWLEDGE: The economic dimension of the cluster

The Spanish ceramics industry – and particularly the Castellón cluster – is one of the country's most significant production ecosystems. To speak of training in ceramics is not merely to speak of education or culture: it is also to speak of competitiveness, employment, industrial innovation and economic sustainability.

Sector data clearly illustrate the scale of this ecosystem. According to ASCER, the Spanish ceramic tile manufacturing sector achieved an estimated turnover of €4.834 billion in 2025, with €3.484 billion coming from exports – around 72% of total sales. The sector produced 423 million square metres and generated 15,939 direct jobs. Furthermore, approximately 94% of domestic production is concentrated in Castellón province, where 80% of the sector's companies are based.

The cluster's significance is not limited to tile manufacture. The Spanish Association of Frit, Glaze and Ceramic Colours Manufacturers (ANFFECC) estimates the frit, glaze and ceramic colours sector turnover at €1.3635 billion in 2025, with exports of €891.4 million, production of 1.5 million tonnes and 4,006 direct jobs. ANFFECC itself highlights that one in four workers holds a university degree, a particularly significant figure that underscores the need for qualified professionals in chemistry, materials science, technical assistance, technology and innovation.

Added to this is the ceramics machinery and capital goods subsector, represented by ASEBEC, whose provisional sales for 2025 stand at around €376 million, with a headcount of close to 1,690 employees. These figures evidence that Ceramics is not a single production activity, but rather a complex and interdependent industrial system, where every advance in materials,

processes, finishes, decoration or machinery requires professionals capable of understanding the system as a whole.

International competition obliges the European ceramics sector to differentiate itself through knowledge, quality, sustainability, technology and design. Competing solely on price is insufficient and unsustainable. From this perspective, ESCAL should be seen as a strategic infrastructure for the cluster: providing training in ceramics means investing in competitiveness, maintaining skilled employment, fostering innovation and sustaining the region's international leadership.

In this context, higher education acts as a unifying force for the entire ecosystem. Manufacturing companies need technicians and designers; firms producing frits, glazes and pigments require professionals with a background in Chemistry and the ability to provide technical assistance; the ceramics machinery sector requires professionals capable of understanding processes, automation and production needs; and creative and design spaces need people with an understanding of materials and design skills. ESCAL can contribute to all these areas because it does not provide training from a single perspective, but rather from a comprehensive understanding of the ceramics industry.

8. EMPLOYABILITY, GENERATIONAL RENEWAL AND NEW CURRICULUM

The high employability of graduates in Ceramics is one of the strongest arguments in favour of this training. ESCAL has historically championed a curriculum closely linked to the professional realities of the sector. Students are not trained for an abstract discipline, but for an ecosystem that demands qualified professionals in laboratories, design, product development, production, quality control, technical assistance, innovation, research, digital decoration, materials formulation, artistic creation, teaching and cultural exchange.

This comprehensive training enables graduates to adapt to such a diversity of roles. Such versatility is particularly important at a time of sectoral transformation. The school must listen to the sector but also anticipate its needs: it must understand its challenges but also forge new paths; it must train students for immediate employability but also for future innovation.

Generational renewal is another crucial challenge. Many young people are unaware that Ceramics can be a field that is technological, creative, scientific, artistic and industrial all at once. They do not realise that behind a ceramic surface lies digital design, chemistry, materials, thermal processes, sustainability, automation, research and international marketing. A specific higher education degree sends a clear message: Ceramics is a high-level discipline, with its own body of knowledge, career prospects and potential for the future.

The update to the curriculum, to be carried out within the framework of Law 1/2024, represents a historic opportunity for ESCAL and for the ceramics industry as a whole. It is not merely a matter of adapting a degree programme to a new regulatory framework, but of rethinking the types of professionals the ceramics sector needs, both now and in the future. The new curriculum must reflect the sector's actual development: the digitalisation of processes, inkjet decoration, functionalisation of surfaces, sustainability, energy efficiency, materials research, the circular economy, automation, artificial intelligence applied to design and production, contemporary creation, visual culture and technology transfer.

The development of this new curriculum should not be seen merely as formal adaptation but as an opportunity for dialogue between the school, authorities, enterprises, technology centres,

sector associations and professionals. The ceramics sector is changing rapidly, and training must be able to respond to these developments without losing its identity. The key will lie in maintaining the comprehensive foundation that makes ESCAL unique, whilst incorporating emerging skills linked to digital transition, sustainability, the circular economy, advanced surfaces and new languages of design and creation.

This process can transform ESCAL into an even more strategic hub for the region. An updated curriculum will enable the school to strengthen work placements, projects with companies, applied research, collaboration with technology centres and a focus on emerging professional profiles. The school can thus become a training laboratory for the cluster: a place where students learn, but also where the sector can identify talent, explore ideas and anticipate future needs.

9. CONCLUSION: Tomorrow's ceramics lie in today's training

The future of ceramics will not be decided solely in factories, kilns, laboratories, at international trade fairs or in marketplaces. It will also be decided in classrooms, workshops, research projects, trials, work placements, collaborations with businesses and in all those spaces where the talent of the future is nurtured.

Ceramics need innovation, but innovation needs knowledge. They need technology, but technology needs sound judgement. They need design, but design needs an understanding of materials. They need sustainability, but sustainability needs research. They need tradition, but tradition needs to be reinterpreted. They need industry, but industry needs professionals.

The *Escola Superior de Ceràmica de l'Alcora* represents a unique and necessary response to this challenge. Its exclusive specialisation in Ceramics, its holistic approach, its connection to the surrounding region, its commitment to technologies such as inkjet printing, its links with industry, its high graduate employability and the development of two specific official master's degrees together form an educational model of enormous strategic value.

This response is particularly valuable because it originates from the region itself. Higher education in Ceramics in l'Alcora is not an out-of-context proposal, but rather a critical and contemporary extension of a deeply rooted material culture. The school transforms ceramic heritage into active knowledge: it draws on tradition, subjects it to research, connects it with industry and channels it towards new forms of creation and production.

For this reason, championing higher education in Ceramics means championing the sector's future. It means championing talent, innovation, competitiveness, regional identity and the capacity for transformation within an industry that has been, is and must continue to be strategic. The ceramics of tomorrow will not merely be the ceramics we know how to produce. It will be the ceramics we are capable of imagining, researching, designing, teaching and transforming. And to achieve all this, there can be no innovation without education.

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