ARTIST'S ARTICLE

Representing Theoretical Physics Research in and on Ceramics

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A theoretical physicist and potter, the author presents his practice that fuses these two sides of himself. His art aims to circumvent the regular pitfalls of scientific public engagement, replacing a didactic approach with sensory stimuli from tactile objects, eliciting curiosity for science. The author presents the origins of his practice and focuses on several series of ceramic pots. He explains the design of their form and decoration, exemplifying the interconnections between physics, mathematics and some of his artistic influences. The paper concludes with a discussion of his experience presenting the work and its reception.

GENESIS
As the pace of scientific revolution has accelerated over the past century, so has the knowledge gap between experts and the layperson [1,2]. Much effort is dedicated to overcoming this barrier with the purposes of educating the public, affecting policy, justifying fundamental research and attracting youngsters to fields of science, technology, engineering and mathematics (STEM) [1]. Common approaches include public talks, popular science books and art-science collaborations.

The more technical, abstract and theoretical the field of study is, the harder it is to bridge this gap. My field of expertise, theoretical high energy physics—encompassing topics like string theory, supersymmetric field theories and higher dimensional gravity—is an example of a rather esoteric topic. Still, quite a few physicists engage the public on it [4–7].

Personally, I have grappled with a sense of isolation, being able to communicate my research only to a small cohort of colleagues. I have attempted to use the regular paths of science communicators but have not found it satisfying. I wish to share something personal—a glimpse of my own research—and the amount of background that is needed to get to the core of it is overwhelming. Instead I found a shortcut to bridge this gap, using my hobby of pottery.

My ceramics journey started with a course at the University of California, Santa Barbara, during my PhD studies. I had previously been exposed to Japanese art and craft via my grandfather, who was a major collector, and had also dabbled in craft as a child. Since that course during my postdoc years, I continued to hone my skills in studios and learned from several teachers (particularly Troy Schmidt and Doron Yaa-kobi). Over time I became a proficient potter, but it remained a crafting hobby.

After securing a permanent academic job, I was finally able to establish my own studio and in parallel started to grapple more seriously with finding a way to make my research relatable. I came to notice that friends would refer to my pottery as my "creative side" versus science, my "mechanical" (and inapproachable) side. I disagree with this distinction, and while there are studies that compare knowledge, skill and creativity in the artistic and scientific realms [8,9], I felt that the connection between the two realms was not commonly accepted or understood.

This was the main driving force for trying to merge my profession and my hobby. I elected to mirror the creativity I recognize in science with the craft generally accepted as creative, which also gave me an avenue to communicate my research to general audiences.

PRACTICE
My approach to presenting science in my art is multilayered. On one level it is very literal as I transcribe formulas, figures and graphs arising in my research on pots. On another level, it is more abstract, where aspects of the physics and math are encoded in the forms and design choices, as I exemplify in the case studies presented below.

For every theoretical physics project that I undertake, I choose a form inspired by the research. I start with rough stone-ware on which I write broad ideas, postulates and possible methodologies. As the research progresses, the formulas get developed and in parallel the material, form and decoration...
get refined. Finally I reach the end result, which is a scientific publication, and I present its contents using the finest materials and techniques available in my studio.

Within my ceramic practice, encompassing high-fired stoneware and porcelain, I experiment with an eclectic range of materials and techniques, as is appropriate for representing the research. The potter’s wheel is often the starting point of my works, but I also employ slab-building and more rarely coiling and slip-casting. To decorate my pieces I use diverse techniques, among them incision, impression, inlay, drawing in colored slip, sgraffito, glazing and over-glazing.

To illustrate my creative process, I chose to organize the rest of this section according to research projects rather than ceramic techniques. I discuss the Cut, Circle, Cusp and Polygons series, outlining some of the scientific research, the resulting design choices and the different ceramic techniques used in them.

**Cut**

The Cut series is based on research with Louise Anderson [10]. The vessels in this series are spherical and there is a cut in them. The sphere represents the topic of our research, which are three-dimensional physical models on spherical spaces. The cut refers to the mathematical phenomenon known as a branch cut [11], which plays a paramount role in our calculations.

When making spherical forms in clay, even if the motivation is related to physics, it is natural to reference Korean moon jars, and I mostly followed the traditional techniques: forming two bowls, placing one upside down on top of the other and joining them at the equator. As for the cut, in addition to the scientific rationale, they also served the role of violating the form, stepping away from craft and functional ware to become artistic representation in clay. As such they also reference the canvases and pots of Lucio Fontana.

Figure 1 shows Cut-21, a porcelain work summarizing the main results of the calculation. Above the cut is the starting point of the computation, which is an integral; the details of the solution are written in a descending spiral, and at the bottom one can see part of a phase diagram that we calculated for this model.

Figure 2 is an earlier piece in the Cut series. At the time I made this pot, the calculations were not yet finalized, so the pot illustrates a draft stage of our work. To indicate that, I finished the vase with a thick application of a shino glaze, which obscured most of the writing. In fact, the glaze sealed the cut. One can make out the same integral as in Fig. 1, and the leftmost point of the cut indicated by the letter A, but the rest of the details, which include many inaccuracies, are largely illegible.

**Circle**

In the Circle series, I revisit research undertaken with my PhD supervisor, which calculates something known as a circular Wilson loop [12]. I chose to represent the project in plates as a reference to the circle.

Figure 4 shows a detail of one of the plates with some of the calculations. The circle and squiggly lines are known as a Feynman diagram [13] and represent particular integrals in the evaluation of the Wilson loop. The rim of the plate is impressed with the identifier of our paper on the theoretical physics preprint repository arxiv.org (hep-th/0010274) [14].

The main result in our paper was a formula, a function of two variables denoted \( \lambda \) and \( N \), which can be seen in the center of Fig. 4. We often assume that \( 1/N \) is very small and organize the calculation in powers of this parameter. For the design of Circle-10 (Fig. 5), I took this exact result and expanded it in that way. One can view the outcome as a sequence of numbers whose importance depends on the power
of $1/N$ they precede. The plate is made of porcelain and for the writing I employed blue clay inlay (porcelain mixed with cobalt carbonate). I diluted the color such that subsequent terms with higher powers of $1/N$ are fainter and fainter, indicating their diminishing importance.

**Cusp**

The *Cusp* series tells the story of a paper [15] that focuses on other examples of Wilson loops, those with a corner. The pots are made of two bent sheets of clay adjoined at two corners, also called cusps. The inspiration for this shape comes from a diagram in our paper of two arcs meeting at two cusps, which is the main object of study.

The result of the calculation depends on the angle at the cusp, and in the process of making some of the pieces I measure this angle. This allows me to evaluate the formulas at this particular angle and thus replace very complicated expressions with concrete numbers. *Cusp-3* (Fig. 3) shows the angle measured as close to 2.22 (denoted by $\phi$ on the left). This work is an example of a very rough decoration of draft calculations.

In our paper we evaluated the cusp using two complementary formulations of the theory ("duality"), and I chose to represent each on one side of the pot. The left-hand image of Fig. 3 shows the field-theory description, similar to the way one studies elementary particles like electrons and quarks.
The illustrations here are again Feynman diagrams as in Fig. 4, now evaluating the cusp.

The right side of Fig. 3 shows the other side of Cusp-3, with the complementary gravitational description of this calculation in terms of minimal string surfaces (like soap bubbles) in curved space.

Figure 6 shows Cusp-20 both during its decoration stage and as a completed work. On the left, the clay is still slightly malleable and has just been inscribed and imprinted (the tools are in the background). The numbers and letter at the base of the pot are the complete bibliography of our paper. Each citation is represented by its identifier on arxiv.org, or a short version of the journal reference. My research is one step in a long process of scientific inquiry, and it is crucial to acknowledge the work that mine builds on. My art likewise builds on ancient and modern traditions, tools and know-how. The technique of incised stoneware with celadon glaze originated in China and was then famously used in Korea (Goryeo ware). Celadon’s semitransparency makes it ideal to highlight textures in the clay, in this case my inscriptions, driving me to this ancient technique.

I presented more details on the Cusp series at the Bridges 2019 conference at Johannes Kepler University in Linz [16].

Polygons
The Polygons series grew out of research related to zigzag paths and polygons in space-time. I decided to use this as the main design element of the ceramics, since such geometric decorations are very common in traditional pottery. The closest reference I found for a simple zigzag pattern was Native American ceramics [17], so I chose a matching traditional form for the works in this series (Fig. 7). I started making these pots in parallel to the research, but soon we ran into trouble and eventually abandoned the project. This is not an uncommon occurrence in science (or art); research is unpredictable and we often do not know in advance whether a problem will lend itself to a solution.

I showed some of these pots in my first solo exhibition and they were very popular. Despite my gallerist’s urging for more Polygons, I stopped making them. I would like to complete the research, but until I do, I cannot make an artistic representation of a dormant project. This series exemplifies the quandary of whether to exhibit works based on unfinished research or work in progress. Is the art complete before the research is? I think so: It illustrates a particular stage in the scientific process. Do I publicize unfinished projects and risk that somebody may steal my ideas or ridicule my mistakes? So far I have chosen to do that, but in the future I may keep works on hold until the corresponding research is published. (I also ask my collaborators’ permission to present our research.)

It is not rare for my ceramic works to contain flaws in both the science and craft. The works representing early stages of the research are made before the solution exists and contain drafts of the calculations, which may prove to be wrong. They sometimes also have blemishes in the clay or glaze—these works are handmade and this is natural. It is certainly embarrassing to realize mistakes in past work, but likewise inspiring to rediscover past achievements and track the changes. These faults and successes are for my audience (be it scientists who know the content of my research or the general public) and me to examine, to see the progress, development and beauty of the imperfections of human endeavor. This is particularly evident in Polygons-5 (Fig. 8), which developed a small crack during glaze-firing. Since I view it as an unacceptable fault, I used the Japanese technique of kintsugi, employing urushi lacquer as adhesive/filler and gold powder to cover the crack, thus turning the crack into a feature.
On both Fig. 7 and Fig. 8 one can see the drawings of the polygons that give this series its name. In Fig. 7 one can also see a space-time diagram around the zigzag pattern, where the diagonal lines represent light rays.

RECEPTION

I was extremely fortunate to find an audience quickly for my art. Within less than a year of starting to make these works I had a solo exhibition in a commercial gallery, and one piece was selected for the Royal Academy of Arts Summer Exhibition. Since then I have had one additional solo exhibition, participated in several group shows and cultivated a large following via Instagram [18]. I try here to analyze my work’s reception as correlated with my expectations.

As a scientist I am accustomed to people finding my work intimidating and often reverting to high school physics traumas that shut them off from science. The reception of my calculations presented on clay is much more open, and from my discussions with viewers I could discern the following reasons.

Many viewers likened my works to hieroglyphics and/or cuneiforms. To me the latter is technically more accurate, as cuneiforms are most often impressed on clay tablets and because they were developed as an accounting system. But the word hieroglyph is also appropriate in the common sense of a cypher. Visitors to Egyptology exhibitions enjoy hieroglyphics without need of translation and with no shame for ignorance of their content; the hieroglyphics are enjoyed as mysterious symbols. Placing mathematical notation within art relaxes the pressure to understand it. As with ancient scripts, mathematics can be enjoyed as the intellectual achievement of others and arouse curiosity rather than fear.

Although I had thought of the analogy with cuneiforms from the onset of this work, I did not realize the extent of its power in making obscure mathematics approachable. I hope that my work will intrigue some to actually pursue math and science. But even if not, it at least humanizes those working within those fields.

In addition, one could appreciate my ceramics purely for their aesthetic value, treating the script as a geometrical pattern. While many are drawn to the pieces with clear text, others prefer those with the text obscured—often people who could understand the formulas would rather not be confronted with a literal piece.

Viewers have asked about the design, the choice of shape and other elements in the ceramics, and also about the particular content of my research. The resulting discussion can go smoothly from basic concepts of physics and math through art theory to the chemistry of glazes, back to some of the intricacies of string theory and maybe the history of ceramics. I find that this resolves much of my frustration with traditional science communication. I do not need to recite the standard lore of string theory and I can present aspects of myself and my personal research interests without delving into increasingly arcane theoretical physics technicalities.

I also present my ceramics to colleagues at seminars and conferences. They often revel in guessing at the internal jokes in my designs, some of which are explained above. I found in many colleagues deep sympathy toward the notion of realizing what to the expert are beautiful results as physically appealing objects. I turned down many requests to represent colleagues’ work in ceramics, having chosen to focus on my research.

I am planning further larger-scale projects, on which I hope to report in the future, but even with my modest beginnings, I feel that I have realized my goal of sharing my passion for science and in particular theoretical physics. I hope that my endeavors have an impact on the public perception of science.
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References and Notes


2 Harry Collins, Are We All Scientific Experts Now? (John Wiley & Sons, 2014).


4 Stephen Hawking, A Brief History of Time (Bantam Books, 1988).


7 Big Think, “Michio Kaku: The Universe in a Nutshell” (Full Presentation): www.youtube.com/watch?v=0NnbJNw46k (accessed 26 November 2019).


17 See e.g. www.collections.si.edu/search/detail/edanmdm:NMAI_207740; www.collections.si.edu/search/detail/edanmdm:NMAI_214990 (accessed 26 November 2019).


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