FIBRE ARTISTS AND OUTSIDER ALGORITHMS: RETHINKING ETHNOMATHEMATICS THROUGH CONTEMPORARY CRAFT

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In 1946, the retired mathematics teacher and novice weaver, Ada Dietz (1882–ca.1970), began to experiment with an unusual method for generating woven patterns. Harnessing the concept of the mathematical formula as inspiration, she devised an algorithmic technique for interpreting polynomial expressions in cloth. After her weaving of $(a + b + c + d + e + f)^2$ caught the attention of the United State's burgeoning community of hobby weavers, Dietz travelled the country, hosting weaving workshops on "the tremendously exciting, unexplored field of algebraics" (Dietz, 1949, p. 3). While for professional mathematicians, 'algebraics' refer to the subset of complex numbers that solve polynomial equations, Dietz's diagram of her award-winning weaving (Figure 1) bears little relation to Argand's vision of the complex plane. How, then, does her curious weaving draft relate to algebraic forms? Moreover, how might Dietz's idiosyncratic vision of algebraics help us to think differently about the teaching and learning of mathematics in informal settings?

Like Dietz, contemporary fibre artist, Sonya Clark (1967–), has long experimented with mathematical technologies and concepts in her textile-driven practice. In particular, her recent works, *Abacus* (2010) and *Unravelling & Unravelled* (2015-2017), can be read as pedagogical projects that implicitly interrogate the mutability of number and structure. Moreover, her work's explicit political engagement with the USA's history of racist oppression foregrounds questions only implicit in Dietz's 'algebraics': Who gets to invent mathematics? What makes something mathematically meaningful?

In pairing the mid-century work of Ada Dietz with these two compelling contemporary projects from Sonya Clark, this article considers the ways in which normative mathematical ideas are remade through their engagement with weaving practice. Through an examination of the unconventional ways in which mathematics inhabits the fibre practices of these two artists, the article explores the manner in which their work opens mathematical concepts outward, toward novel and inventive acts of appropriation. Outsiders to the world of professional mathematics, Dietz and Clark's 'queer use' (Ahmed, 2019) of mathematical tools enacts a playful disobedience toward mathematical forms that highlights the gendered and racialized histories in which these conventions are embedded. In showing how mathematical concepts "can be used in ways other than for which they were intended or by those other than for whom they were intended" (Ahmed, 2019, p. 199), their examples help us to see how both mathematical and cultural forms can be remade and re-evaluated through open-ended and playful material experiments with fibre.

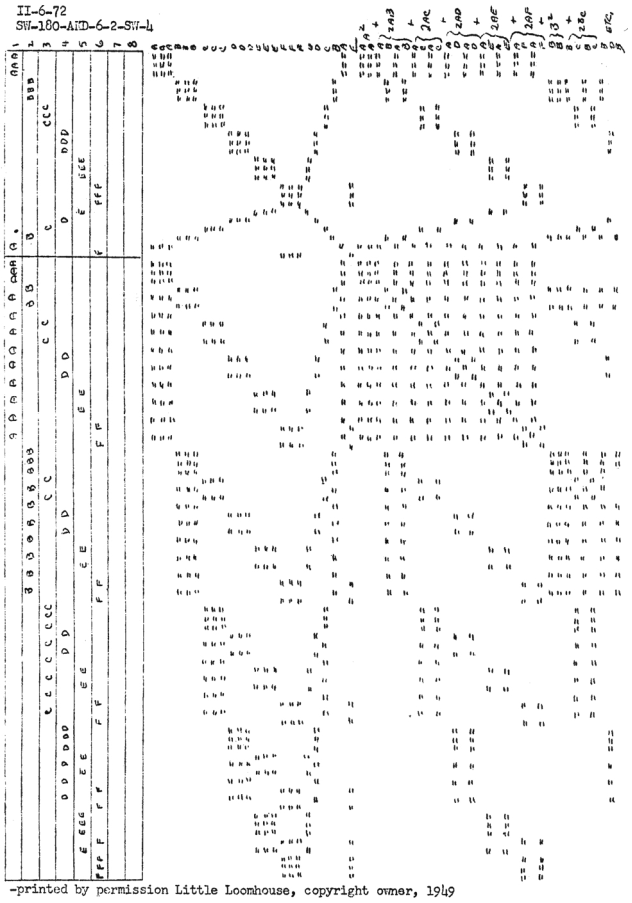


Figure 1. The final page of Ada Dietz's Algebraic Expressions, Handwoven Textiles (1949, p. 35).

Textile practices have commonly been taken up in ethnomathematical research, a field that locates representations of mathematical concepts in the creative expressions of particular cultures. While ethnomathematicians tend to measure their claims against putatively established mathematical truths, the case studies in this essay showcase ways in which outsiders have engaged on their own terms with mathematical forms, inventing *new* mathematical worlds and generating *novel* sensibilities for pattern and structure. Dietz and Clark's creative misuse of mathematical tools challenges the claim that mathematical cultures are discrete and finished entities. By performing mathematics in ways that cannot be evaluated as right or wrong, I suggest that these projects generate novel mathematical sensibilities through their development and exploration of *outsider algorithms.* In the case studies that follow, the fibre projects of Dietz and Clark recast mathematics as made by thinking *through* materials and *in* community. Espousing the powerful notion that mathematics is a responsive and contextually driven enterprise, outsider algorithms offer insight into a critical mathematics pedagogy that understands mathematics as not only *in* the world but also vital to its transformation.

Queering ethnomathematics

In the last two decades, a great deal of interest has erupted around the mathematics entailed in fibre practices. Projects, such as the works of Wertheim (2005) or Yackel & belcastro (2018), rethink both classroom-based and public encounters with mathematics through textile practices. They expand on long-standing interest in exploring non-Western fibre practices as 'ethnomathematical' practices. Spanning from Gerdes's (1988) explorations of basket weaving in Mozambique to more recent investigations of mat weaving in the Sulu Zone by de las Peñas, Garciano & Verzosa (2014), ethnomathematical research aims to develop our sensitivity to unconventional mathematical practices. It seeks to transform mathematics education to reflect the distinctive cultural underpinnings of mathematical thinking (d'Ambrosio, 1985).

Despite its decolonial ambitions, ethnomathematics has long been critiqued for the way it often relies on formal or 'Western' mathematics as a frame of reference for recognising ethnomathematical practices (Vithal & Skovsmose, 1997). In its efforts to identify and demarcate diverse expressions of mathematical ideas, ethnomathematical research can inadvertently reinforce the notion that both culture and mathematics are static categories. This is because when ethnomathematics merely adds to the diversity of mathematical expressions, it fails to challenge the founding myth of mathematics as ultimately unmarked or acultural. Nevertheless, Gutiérrez (2017) opens up a new conversation with ethnomathematics by offering the term *mathematx* to reference Mayan and Nahuas approaches to mathematical activity. She proposes a philosophical grounding to mathematics that values more-than-human mathematical relations with particular lands and living beings. Pushing this thinking further, Gholson (2019) suggests that we must also grapple with the way in which mathematical knowledge may figure differently across the sometimes contesting claims of Indigeneity and Blackness.

In the following case studies, mathematical and woven forms are entangled in *outsider algorithms,* enacting possibilities that move toward more open-ended encounters for ethnomathematics. As communal projects, which enlist the pedagogical powers of textile technologies, these artworks entail a particular kind of thinking and doing that queer normative notions of mathematical creativity and agency. Following Ahmed's (2019) notion that the queer archive lives "in a gap between what is and what is in use" (p. 208), these projects can help us to rethink ethnomathematics as a creative practice that digs into that inter-space. If as Tahta (1980) argues, mathematical learning begins with a qualitative *awareness* of imagery and dynamics, the case studies presented here move to extend this *awareness* to the active use of materials and tools.

In reading these projects as pedagogical performances, this article addresses the ways in which learning mathematics is about developing attentive relations across humans, algorithms, materials and histories. The strange polynomial patterns and tactile modes of counting (and accounting) that characterise the fibre work of Dietz and Clark raise important questions about the nature of mathematical invention, play, learning and unlearning: How does fibre change mathematical tools? Where do lived realities and abstract forms meet? How do we contend with the ways in which mathematics both participates in and opposes injustice? Paying attention to the 'undisciplined' appropriations and playful experimentation in these communal projects, these case studies reckon with what it is to learn and do mathematics in an unjust world that is also unfinished.

Community organising

Little is known of Ada Dietz's early life, other than the fact that she came to weaving as a retired mathematics teacher. Much of what we do know about her derives from *Algebraic Expressions, Handwoven Textiles* (1949), the short draftbook [1] developed to document her algebraic methods. Characterising the incredibly bookish, or, more specifically, 'textilish', manner in which hobbyist weavers pursued new ideas, this text is a collaborative compilation of writing, image and diagram. It gives an intimate picture of how a community of primarily white middle-class women grappled with anxieties about creativity, modernity, and mathematics at mid-century in the US. Navigating weaving's associations with mechanised production, feminized materiality, and mathematical pattern, Dietz's draftbook intervenes in the intense debates within her community around how weaving might 'go modern'. Implicitly addressing these concerns, the text opens by describing her turn to mathematics:

> A formula in mathematics occurred to be the most definite basis from which to work […] As patterns grew and the possibilities opened up, I found that mathematics gave the beautiful space divisions, proportions, and individuality of pattern which the artist strives to achieve. (p. 2)

Here, Dietz secures her inventive choice in the 'definite' nature of mathematical forms. Hailing algebraic patterns as a flexible way of working that "gives the weaver leeway for

creative interpretation" (p. 3), her text also bids co-conspirators to openly explore what she describes as novel mathematical and artistic frontiers.

Given her appeal to the unambiguous or 'definite' nature of mathematics, Dietz's algebraic method is not what one might expect. To get a sense of how it works, we return to Figure 1, whose label 'II-6-72' (on its top left) hints at how Dietz organised her work according to two inputs: 1) the number of variables in the polynomial and 2) the power to which they are collectively raised. 'II-6-72' refers to a polynomial of degree two (II), containing six (6) variables: $(a + b + c + d + e + f)^2$. To render this as a drafting code (of 72 letters), Dietz instructs her readers to expand this expression as they learned in school:

$$(a + b + c + d + e + f)^2 = a^2 + 2ab + 2ac + 2ad + 2ae + 2af + b^2 + 2bc + 2bd + 2be + 2bf + c^2 + \ldots$$

Removing constant terms,

$$aa + ab + ab + ac + ac + ad + ad + ae + ae + af + af + bb + bc + bc + bd + bd + be + \ldots$$

she treats this expanded expression as a coded sequence without operations:

aa/ab/ab/ac/ac/ad/ad/ae/ae/af/af/bb/bc/bc/bd/bd/be/be/bf/bf/cc/cd/cd/ce/ce/cf/cf/dd/de/de/df/df/ee/ef/ef/ff

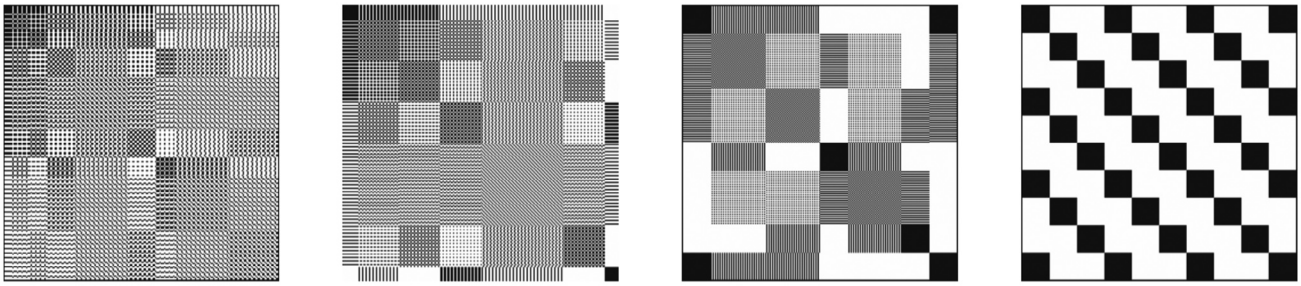
This pattern of letters is visible across the top and down the left side of the draft's music-like notation bars (though, Dietz also added a bordering pattern). Each double tick (") in the diagram's centre shows when a vertically running warp thread is to be lifted over the horizontal wefts, unfolding a diagonally-symmetric pattern by crossing 'II-6-72' with itself.

In this draft, Dietz correlates each variable in her code to a particular harness (the loom's mechanism for raising threads), generating a direct visual and mechanical link to the polynomial's algebraic expansion. However, other parts of her text demonstrate how to employ algebraic patterns of five or more variables on looms with only four harness options. By allowing variables to represent patterned sequences, rather than merely a one-to-one correspondence between variable and material, Dietz stays attuned to the needs of her readership, many of whom owned hobby-looms with only four moving parts. Dietz's deference to the material limitations of her readers points to how her interest in *weaving* algebraic patterns pushed her to consider more complex sequences of code. The malleability of her algorithmic method enables experimentation with *outsider algorithms* across a vast array of patterns, tools and weaverly skill (Schneider, 1998).

Dietz's work illustrates a certain epistemological disobedience toward the usual ways of representing polynomials. While leaning on the formalised mathematical syntax that dictates how variables are organised (alphabetically and according to their exponential degree), Dietz's algorithmic form brazenly flattens the mathematical difference between addition and multiplication. Instead of paying heed to the conventional manner in which algebraic techniques meaningfully connect arithmetic calculations with spatial concepts from geometry, she redirects the slipperiness of algebraic variables to generate patterns that work within the constraints and capacities of the loom. In doing so, Dietz expresses a sensibility towards her tools, in this case both the loom and the weaving draft, and her audience, hobby weavers primarily interested in play not utility. Dietz's approach involves a direct but non-instrumental appropriation of mathematical ideas in an effort to do something new and artful. Exemplifying the mobilisation of algorithm as a machine whose outcome is not known in advance, her somewhat bizarre mathematisation is neither a diminished form of making nor a misunderstanding of mathematical reality. In asking her students to experiment with and become attuned to new rules and conventions, Dietz's *outsider algorithm* springs to life as an unpredictably prolific taxonomy of polynomial weaves.

The lively possibilities of Dietz's inventive praxis are best demonstrated by the work of Ralph Griswold (1934–2006), who began to explore the dynamic and variable structure of what he dubbed "Dietz polynomials" (2001, p. 2) in the early 2000s. Griswold, a computer scientist recognised for his research on early programming languages and symbolic computation, developed a fascination with weaving late in life. Collecting and digitising a large library of weaving documents at the University of Arizona, Griswold penned many short articles exploring the fusion of mathematical and weaverly concepts. While his writing also addressed how contemporary mathematical research on fractals and cell automata can generate new weaving patterns, Griswold was particularly taken with the playful rigour of Dietz's algebraics.

Unfazed by the fact that Dietz's algorithm produced outputs that were in some senses "not mathematically sound" (p. 1),



$(a + b + c)^4$ $\quad$ $\partial((a + b + c)^4)/\partial a$ $\quad$ $\partial^2((a + b + c)^4)/\partial a^2$ $\quad$ $\partial^3((a + b + c)^4)/\partial a^3$

Figure 2. Griswold's (2002) renderings of $(a + b + c)^4$, along with its first, second and third derivative with respect to a.

Griswold set out to examine and expand the language of Dietz's algorithmic method through computational imaging. Observing that Dietz's ideas do operate according to a rigorous algorithmic form, with precise rules for variation, he advanced Dietz's interest in the relationship between her algorithmic inputs (II-6) and the final length of the output pattern (72). He also generated a large visual index of digital weaving patterns, analysing what impact the algorithmic inputs have on the "degree of interaction" (p. 1) of different weaving structures. Elaborating on this work the following year, Griswold (2002) expands Dietz polynomials by creating algorithmic techniques for dealing with negative and fractional coefficients, modular reduction and derivatives (Figure 2). Griswold's reflection on these matters is telling:

> If there are negative coefficients, the question is how to interpret them in the concatenation step. There is no inverse to concatenation like subtraction is to addition. One option is to discard terms with negative coefficients. Another is to ignore the signs in the concatenation step, which is equivalent to using the absolute values of coefficients. Neither of these alternatives makes any sense mathematically, but more important, *they do not add anything to design possibilities.* Instead, there is an opportunity here to add an additional degree of control in the construction of design sequences—if a coefficient is negative, reverse the subsequent sequence of variables before repeating it; the sign of the term determines the direction. (p. 2, emphasis added)

True to Dietz's spirit, Griswold's notes reflect not only a sensitivity to the context of her ideas but also demonstrate how mathematical reflection is animated by this sensitivity. Concluding that, "we have just touched on the possibilities for design based on multivariate polynomials and operations on them" (p. 6), Griswold's investigations greatly expanded Dietz's original idea, visually exploring the 'algo*rhy*thmic' nature of this polynomial practice.

While the authoritative language that opens Dietz's text boldly folds her algorithm into the advancement of civilisation itself, its closing lines point more softly to the text's feminist ambitions: "It is not at all uncommon to see a man muttering to himself or scribbling on an envelope and then share his thrill as he ties the equation to the fabric" (1949, p. 36). Delighting in the discomfort that an authorising eye might experience in making sense of Dietz's algebraic forms, Dietz celebrates as 'thrilling' the discovery of new ways of seeing polynomial pattern. It is with Griswold that this *outsider algorithm* takes on a life of its own. Exceeding Dietz's individual intentions, patterned plaids are connected across a kind of calculation that foregrounds inventive technique over mastery of mathematical form.

Figure 3. Sonya Clark, Abacus, 2010, wood, metal and human hair. 5 x 5 in^2 (12.7 x 12.7 cm^2), photo credit: Taylor Dabney

Cultural fabric and accountability

Sonya Clark's *Abacus* (2010) is a small square frame laid out in the classic seven-bead formation of the historically Chinese *suanpan*, or calculating tray. A mathematical instrument still used widely in Asian contexts and easily recognisable to a Western audience, Clark's *Abacus* consists of four parallel steel rods in a simple wooden frame. A longitudinal beam splits the rods into upper and lower decks, so that some of its beads rest on the outer edges of the abacus's frame while others are nestled against its dividing lintel (Figure 3). Unlike Dietz, whose work was shared informally amongst weavers, Clark's status as an internationally recognised artist means that encounters with this work happen in a gallery. Spectators are left to lean in and wonder what to make of the careful placement of its beads. Does this arrangement contain a pattern or a number? What calculation could be underway?

It is in looking closely at its beaded formation that something unusual about Clark's device comes into focus. Dense, dark, and evenly formed—at first glance, its beads have the convincing shape of the squat hardwood cylinders that commonly click and clack across an abacus's frame. However, closer inspection reveals that the beads of this abacus are cloaked in a fuzzy halo of stray fibres. They are made from Clark's own kinky, brown hair. Otherwise unadorned, Clark's *Abacus* is suddenly saturated with an uncanny feeling: What kinds of calculations does such a machine make? Can the presence of this fibre change the workings of this mathematical tool?

Sonya Clark is a prominent American fibre artist and fierce advocate of craft processes as a means to both unravel and retangle new histories and new knowledges. Her work explicitly interrogates markers of African American identity through the incorporation and transformation of materials at the heart of America's racialized history: sugar, copper, cotton, and hair. For Clark, hairdressing constitutes the primordial fibre art, one that can serve to reconnect histories ruptured by enslavement and systematic racism (Clark, 1997, 2015). As a marker of both collective and individual identity, Mercer (1987) argues that "black people's hair has been historically devalued as the most visible stigma of blackness, second only to skin" (p. 35). Yet, in Yoruba philosophies, from which Clark draws, the head is a sacred site and hairdressing its glorifying crown (Gaskins, 2015). Like the politically motivated work of ethnomathematical scholars, Clark's *Abacus* reminds viewers that mathematics and measurement have been directly involved in the counting and objectifying of human bodies. Importantly, however, the malleability of Clark's *Abacus* opens out onto the unfinished nature of scientific and mathematical ideas.

The abacus, while a sophisticated tool for advanced counting and calculating, is notably at odds with the alphanumeric emphasis of many mathematics curricula. Functioning without symbols or written number, Clark's *Abacus* draws special attention to the mechanical and sensorial modes of counting invoked by this instrument. The soft and unpredictable edges of its beads respond to engagement, changing in shape through use. Cutting across the definite nature of number, *Abacus* explores the im/permanence of the ledger and the ways in which numbers live in material accounts.

Clark's stop-motion video of *Abacus* [2] begins by counting upward from 1,863. This number refers to the year—1863—in which Abraham Lincoln issued the Emancipation Proclamation, a document that, while initially limited in scope, eventually led to the freeing of all enslaved people in the United States. In the same way that cultural readings of Black hair are both overdetermined and underdetermined, this mathematical tool counts time in a manner that is universal and particular all at once. Clark's *Abacus*, like number itself, oscillates between general conceptions of counting/time and the specificity of counting forward from emancipation. Holding in tension the one and the many, *Abacus* presents an algorithmic form open to magical and monstrous calculations, yet tied to specific materials and identities. This *outsider algorithm* teaches viewers to recognise their relationship to both history and number as an artefact of their particular historical subjectivity, not limited to a fixed or universal interpretation.

Clark's *Unravelling* (2015, Figure 4) is a performance work that continues this theme. Introducing gallery participants to a novel relationship with cloth and material structure, it points to the subtleties hidden in our everyday encounters with textiles. Conjuring a learning group from those who show up in the gallery, Clark invites visitors, one-by-one, to step forward and learn to unpick the Confederate flag at her side. She shows audience members, who may be unfamiliar with weaving processes, how to handle this charged symbol as an object with a specific history, made according to an algorithmic number pattern. Guiding participants to see and feel the thin cotton threads that form the cloth's crosshatched weave structure, Clark asks them to attend closely to structure and pattern in their work to break down this emblem of white nationalism. Participants' delight and frustration in the slow and careful work of unmaking becomes "an apt metaphor for the work and care it will take to dismantle the racism embedded in the fabric of America" (Clark & Packard, 2015, para. 5). However, through Clark's insistence on a particular investigative method, *Unravelling* also enacts a pedagogy for understanding structure that opens out onto an unfinished world.

Here, as in *Abacus*, a fraught *cultural form* intersects with conventional ideas about *abstract form* found in mathematics. In both works, Clark sets out to create objects that think and measure time in new ways. As participants learn to recognise the flag's discrete parts, they may find themselves seduced by the surprisingly easy algorithm of isolating warp threads from weft. At the same time, they can become overpowered by the slow and measured nature of this work—especially in comparison to the powerful industrial looms that put it together. In turning to *Unravelling's* sister

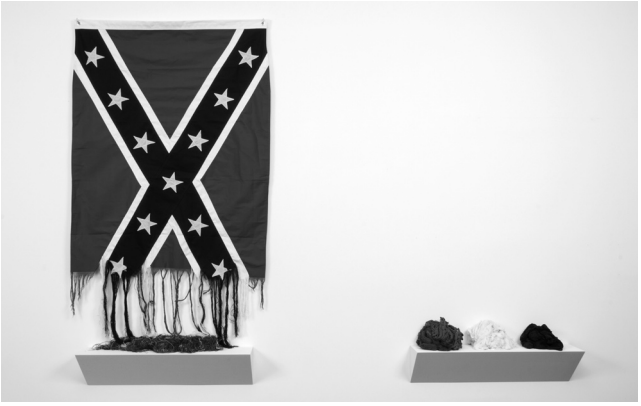


Figure 4. Sonya Clark, Unravelling & Unravelled, 2015, unravelled and partially unravelled Confederate Battle flags. Photo credit: Taylor Dabney

work, *Unravelled* (Figure 5, right), where the Confederate flag is displayed as three piles of coloured thread, gallery visitors are ushered toward informal questions involving estimation and measure: What will it take to complete this task? What happens when this symbol is broken down and divided into wisps of thread? What are we to make of the pieces? This work forces us to notice that these piles of thread, unravelled from a symbol of racialized hatred, could easily be used to construct the red, white and blue of the US national flag. Materially exploring how woven structures come apart inevitably leads us to ask: What *new* forms can we make from these salvaged fibres?

In their raised state of awareness, visitors learn to recognise the discrete parts that make up this seemingly continuous woven plane. Moreover, because they reckon with the counting and sorting that happens at the loom in reverse, they develop their own tactile strategies for imagining what makes up its symbolic form. Through the development of *outsider algorithms* between their fingers and fine filaments of thread, Clark's project conjures the structure and pattern of absent machines, invisible labours and hushed histories.

The art of unravelling a familiar symbol allows us to take note of how cultural forms enlist the paradoxical power of mathematical pattern—both oppressive and unstable, dominant and precarious, ideal and sensorial. Clark's work underscores the temporality of form, its 'made' qualities, and its provisional existence. Although we tend to think of mathematical forms as untouchable, fixed and static, many scholars have pointed to how sensations and speeds sustain these forms through the mathematical constructions associated with a particular concept (de Freitas, Sinclair & Coles, 2017). While we imagine the circle as a static mathematical ideal, we may also learn to recognise it as a dynamic relation of changing movements. The unravelling of the Confederate flag is similarly destabilising: Is this cloth divisible? Into what kinds of parts? What does it mean to separate threads based on colour? To decompose the interwoven lines and invisible rules that make up this flag and its racist history? It is the hypothetical answers to these questions that are at the heart of *Unravelling*'s metaphorical power—a metaphorical reach made possible by the performativity of fibre materials

and fibre processes. Questions of mathematical form quickly double over and percolate across overlapping social notions of division/divisiveness, freedom of movement, equality and identity. Whether or not museumgoers learn to decipher the technical operations of *Abacus* or can account for the exact algorithmic nature of weaving, these performances ask viewers to reconsider the definitive nature of the stories we tell about both American history and, in more subtle ways, number itself.

Conclusions

Given that Dietz's draftbook uncritically addresses learners as pioneers, we may desire, with Toni Morrison:

> to draw a map, so to speak, of a critical geography and use that map to open as much space for discovery, intellectual adventure, and close exploration as did the original charting of the New World—without the mandate for conquest. (1992, p. 3)

Ethnomathematics has long tackled complex questions about the nature of this map: How to make sense of 'outsider' practices in relation to institutionalised versions of mathematics? Nevertheless, it has often struggled to celebrate playful mathematical practices that refuse easy 'translations' of cultural knowledge into recognisable accounts of mathematics from authorised school curricula. Although they operate outside the purview of ethnomathematical practice, Dietz and Clark enact mathematico-scientific exploration in ways that playfully pervert this genre. Their work implicitly explores the gendered and racialized nature of mathematical cultures by brazenly co-opting and reinventing mathematical representations and tools through experimental postures. We learn from these makers how to open up mathematical learning toward experiences that risk new meanings and discoveries.

While Dietz and Clark are very different makers, their projects instantiate *outsider algorithms*—or the queer reuse of mathematical concepts—as important experiments in informal mathematics. In the case studies discussed, mathematical meaning is cultivated through a future-facing sensibility for a diverse and malleable set of algorithmic possibilities. Whether this mathematical inquiry is made explicit or allowed to simmer under the surface, these projects hold in tension the diversity of ways in which the development of algorithmic techniques can reshape our relations to power through the analysis of pattern. In both cases, mathematical exploration is continually refolded into a weaverly awareness of material traditions, be these traditions held within a loom's mechanical connections or traditions upheld by the ways in which American slavery is "obsessively present" in our everyday encounters (Glissant, 1989, p. 64).

Pushing us to rethink informal mathematical learning as firmly connected to uneven histories of colonisation, slavery and patriarchy, these case studies advance playful pedagogies that allow us to look newly upon the material practices involved in the learning and doing of mathematics in informal settings. Their insistence on attentive relations between materials, histories, identities and concepts enact a creative and unfinished exploration of a mathematics that is always already in the world. Most of all, their projects cast new light on the creative consequences and power of mathematical 'misuse'.

Notes

[1] Weaver's use the term 'draft' or 'draught' to refer to the diagrams that they develop in planning their work and communicating their ideas to others. A book of these weaving patterns is called a 'draftbook'.

[2] See Clark's video of *Abacus* in action at: https://youtu.be/tzrJk25QpDo

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