Maths Craft New Zealand: An Unexpected Journey

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Abstract

Maths Craft New Zealand is a non-profit initiative founded in 2016 and run by mathematicians Dr Jeanette McLeod and Dr Phil Wilson from the University of Canterbury. Together with the rest of the Maths Craft Team, we bring maths to the masses by celebrating the links between mathematics and craft. Our aim is to show young and old alike the fun, creativity, and beauty in mathematics through the medium of craft, and to demonstrate just how much mathematics there is in craft. After all, maths is everywhere! Since our inception in mid-2016, Maths Craft have run numerous festivals and workshops across New Zealand, and have reached over 10,000 people. We have secured over NZ$275,000 in grants, sponsorship, and in-kind support, and we are the largest maths outreach programme in New Zealand.

Mathematics is overlooked as a subject of beauty and imagination, with many people viewing it as boring, irrelevant, and downright unpleasant. In fact, as mathematicians, the most common response we hear when we talk to lay-people about our job is: "I hate maths!" In 2016, we founded Maths Craft New Zealand as a way to connect with these people, whether they are struggling students or adults traumatised by childhood memories of maths class. Our aim is to bring maths to the masses, through craft.

Craft has once again become very popular in the public imagination, with knitting groups in every town, colouring books in every bookshop, and the uprising of the maker movement. As mathematicians and crafters, we have always been struck by the many links between mathematics and craft. Not only does craft require a lot of mathematics – from the geometry of origami to the calculations involved in a complex knitted design – but craft is an ideal (and tangible) way to communicate often esoteric mathematical ideas. It is non-threatening and playful, accessible to everyone, and the antithesis to all of the commonly held stereotypes about mathematics.

For the past three years, Maths Craft have been running free, publicly accessible Maths Craft festivals across New Zealand. These one- and two-day events provide a welcoming and non-threatening environment where people can engage directly with the mathematics in craft and the craft in mathematics. Participants are encouraged by specially trained volunteers to try a craft at one of the numerous hands-on craft stations, or to listen to public talks from mathematicians and crafters about the intersection of maths and crafts. Maths Craft also run workshops for smaller groups and have recently started running professional development workshops for school teachers to help them bring Maths Craft into their maths class.

To date, Maths Craft have reached over 10,000 people across New Zealand and we are the largest maths outreach programme in the country.
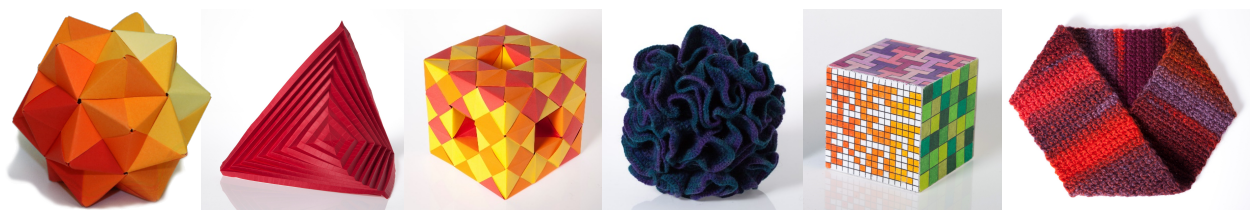
Figure 1: *A selection of craft objects made by Maths Craft for display at Maths Craft events.*

The Journey So Far

The first Maths Craft Festival was the creation of Dr Jeanette McLeod (first author) and Dr Julia Collins (Australian Mathematical Sciences Institute), after a serendipitous encounter while Julia was on holiday in New Zealand in 2016. Jeanette and Julia – both avid knitters and crocheters – wanted to find a way to share the beautiful mathematics behind craft with the public. Jeanette pitched the idea to a National Centre for Research Excellence, Te Pūnaha Matatini, who not only offered to be the major sponsor, but encouraged Jeanette and Julia to "think big". With that, the first Maths Craft Festival was born.

Figure 2: *The 2016 Maths Craft Festival.*

The inaugural Maths Craft Festival was held in September 2016 at the Auckland Museum (Figure 2). It was the first of its kind in New Zealand and it was an immediate hit, attracting over 1,800 visitors and making an appearance on national TV news [19]. It was the largest event run at the Museum in over six months, and was praised by Museum staff for not only its popularity but for attracting such a diverse group of people. The Auckland Museum now considers this the model for successful science outreach events.

The festival was conceived as a one-off event, but following its success, Maths Craft were inundated with requests from around the country to repeat the event, to make it bigger, and to take it around New Zealand. With Julia having left New Zealand, Jeanette assembled the Maths Craft Team and in 2017 and 2018, in response to these requests and funded by a government grant, Maths Craft went on the road. We were invited back to the Auckland Museum and (in an unprecedented move) were given their largest exhibition space, the Event Centre, for three days free of charge. The 2017 Maths Craft Festival attracted almost 3,400 people over a weekend and was one of the largest events hosted by the Museum in 2017 (Figure 3). Our day-long events, the 2017 and 2018 Christchurch Maths Craft Days in The Great Hall and the 2018 Dunedin Maths Craft Day at the Otago Museum, attracted 1,800, 1,000 and 1,100 people respectively, and our 2017 Christchurch event was again featured on national TV news [20].

Figure 3: *Almost 3,400 people attended the 2017 Maths Craft Festival at the Auckland Museum.*

In addition to these large events, we also run workshops and participate in other STEM Festivals around New Zealand. In fact, we currently receive more invitations than we can accept!

The Maths Craft Festival Model

Maths Craft festivals are hands-on celebrations of mathematics, open to everyone: experts and amateurs, maths-fans and maths-phobes, the crafty and the curious. As Maths Craft has grown, we have developed and tested a model for one- and two-day Maths Craft festivals which combines a variety of elements to help the public to not only engage with mathematics, but to enjoy it.

First and foremost, we take a curiosity-driven, playful approach to mathematics, with an emphasis on the importance of making mistakes and not always knowing the answer. At our festivals, we are careful to convey that mathematics isn't about getting an answer which is either right or wrong, but about the journey of discovery and the questions we ask along the way. This is what it means to *think like a mathematician*, and through craft, we give people a way to experience this for themselves.

To achieve all of this, we employ: a selection of hands-on craft stations; a team of 20–40 specially trained volunteers with backgrounds in mathematics; detailed instructional handouts for all of the crafts on offer; free craft supplies; and a series of public talks about the intersection of maths and craft. We also strive to create a welcoming and non-threatening environment where participants are encouraged to stay and craft all day in dedicated crafting areas where volunteers are always on hand to help. Finally, we secure funding through grants, sponsorship, and in-kind support so that we can keep our festivals free and accessible to everyone.

Hands-on Craft Stations

Figure 4: *The Origami Station at the Christchurch Maths Craft Day during the festival (left) and before the festival on setup day (right). Venue: The Great Hall in The Arts Centre, Christchurch.*

Our craft stations (Figure 4) are one of the core components of Maths Craft festivals. At the stations, festival participants are encouraged to try a range of mathematical crafts such as folding an origami octahedron, knitting a mathematical knot, crocheting a Möbius strip, or flexing a hexahexaflexagon. We typically have 5–10 craft stations at a festival, each supervised by 2 or 3 volunteers and featuring a range of activities. For instance, at our crochet station, people can crochet a hyperbolic plane or two variations of a Möbius strip. At each station, we provide detailed written handouts for each craft, copies of which are also available from our website [9]. We make sure that as many of our crafts as possible are entry level, and for those which have a steeper learning curve, such as crochet and French knitting, we have also written basic "how to" handouts. To date, we have developed 12 different craft stations which incorporate the following mathematical concepts:

- **Colouring:** the four colour theorem [5], Latin squares, pursuit curves, impossible triangles.
- **Crochet:** hyperbolic planes [14], the Möbius strip [2,17].
- **Drawing:** pursuit curves, impossible triangles [15].
- **Escher Tiling:** tessellations.
- **Flexagons:** tetraflexagons, trihexaflexagons, hexahexaflexagons [4,18].
- **French Knitted Knots:** knot theory [1,2], topology [2].
- **Meanders:** drawing algorithmically, the seven frieze groups [3].
- **Menger Sponge:** fractals [12].
- **Möbius Strips:** the Möbius strip, topology [2,17].
- **Origami:** polyhedra - cubes, small triakis octahedra, small triambic icosahedra [6,7,13].
- **Penrose Tiles:** non-periodic tilings [16].
- **String Art:** parabolas, concentric circles, cardioids.

In addition to these craft stations, we have a Greeting Station where volunteers greet people as they enter the festival, tell them about Maths Craft, the activities on offer, and the public talk schedule. There are also goodies such as stickers, pens, and bookmarks for people to take away with them. As people leave the festival, they pass by an Exit Station where a volunteer asks them if they would like to take a survey on one of the laptops we have set up and gives them a Maths Craft bag to carry home their crafts.

Volunteers

We require 20–40 volunteers to successfully run a Maths Craft festival. Volunteers help at the craft stations to explain the concepts and assist people in making craft objects (Figure 5), at the Greeting Station to greet and direct people, and in the crafting areas where people sit down at tables to work on their craft projects. They also make sure that each craft station has enough resources, and organise surveys at the Exit Station. All of our volunteers are given red Maths Craft t-shirts and name tags to make them easily identifiable to visitors.

Figure 5: *Volunteers (in red t-shirts) working at the craft stations at various Maths Craft festivals.*

Before each Festival, we run training sessions for our volunteers, teaching them how to create each of our crafts, explaining the mathematical concepts behind them, and giving an overview of good science communication practices. Each training session takes about 2 hours and we try to keep the number to 15-20 people per session. We have now trained over 100 Maths Craft volunteers.

Our volunteers include university undergraduate and postgraduate students in mathematics and science, school maths teachers, academics, retired mathematicians, professionals with mathematical jobs, and crafters (Figure 5). They span all ages with the youngest in their late teens and the oldest in their 70s. Many of them now volunteer for us on a regular basis and have developed a strong interest in science communication.

Handouts

Our detailed instructional handouts on a range of mathematical crafts are the cornerstones of Maths Craft events. To date, we have written over 30 handouts and we are developing more all the time (Figure 6). The Maths Craft Team wrote all of the handouts, took all of the photos and made all of the objects shown in the handouts. Our handouts are licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives international license and are freely available from the Resources section of our website [9].
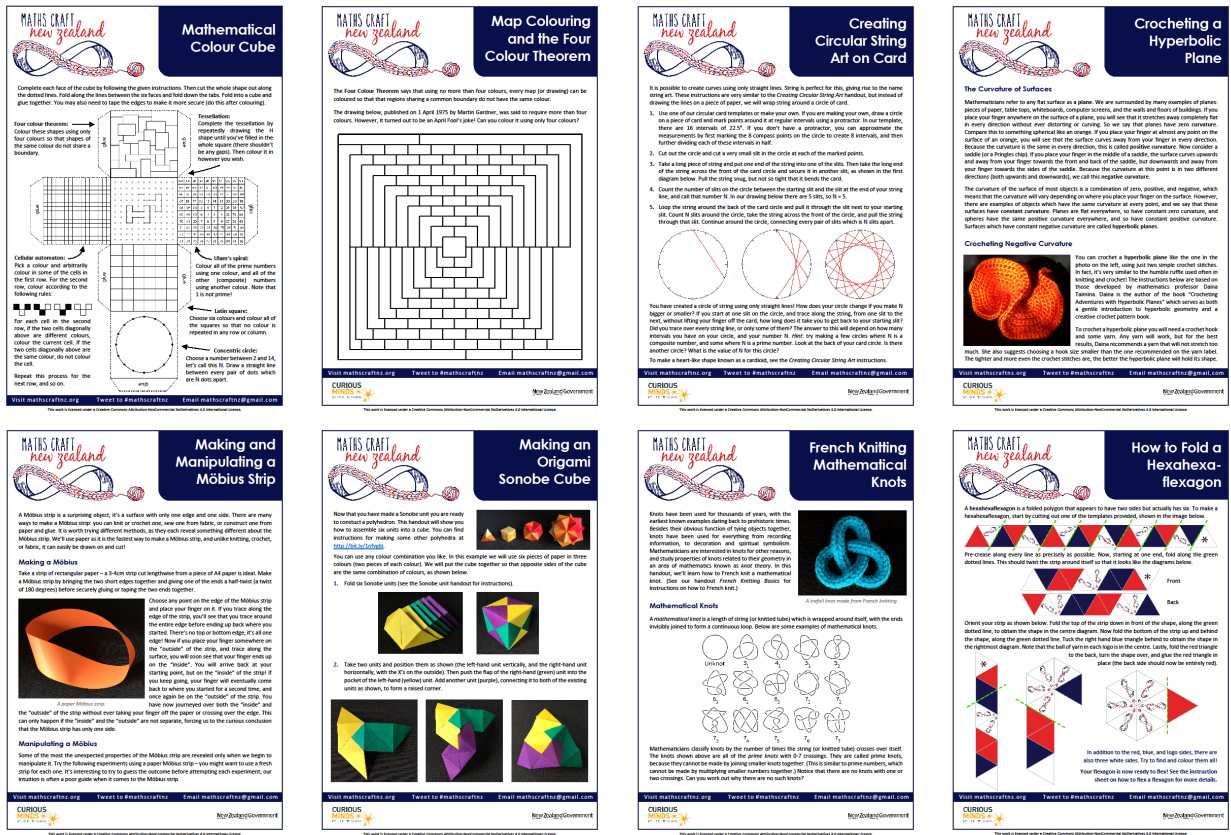

Figure 6: *A selection of Maths Craft instructional handouts, available at festivals and from our website.*

Public Talks

At each Maths Craft Festival, we hold a series of 3–7 public talks depending on the duration of the festival. (One-day events typically include 3 public talks, and two-day events have 6–7.) We invite mathematicians and crafters from around New Zealand and Australia to talk about the connections between maths and crafts in their work. See the Events section of our website [8] for details of talks given at each event. Below is a selection of public talks given at recent Maths Craft festivals:

- Dr Michael Assis (University of Melbourne): *The beauty of origami/The beauty of mathematics – connecting folds.*
- Ms Elizabeth Chesney (University of Canterbury): *Knuts about Knitting Knots.*
- Prof Graham Farr (Monash University): *Making Links and Breaking Codes: The Mathematics of Bill Tutte.*
- Prof Bernd Krauskopf and Prof Hinke Osinga (University of Auckland): *Chaos in Crochet and Steel.*
- Prof Clemency Montelle (University of Canterbury): *The (a)symmetry of a sari.* (Figure 7.)
- Assoc Prof Burkard Polster (Monash University): *What is the best way to lace your shoes?*

Figure 7: *Prof Clemency Montelle giving a public talk at the 2017 Christchurch Maths Craft Day.*

The Team

The first and second authors of this paper are the Director (and co-founder) and Deputy Director of Maths Craft New Zealand respectively, and are research mathematicians at the University of Canterbury. We run Maths Craft New Zealand with the help of the Maths Craft Team - a team of seven people with a range of mathematical backgrounds, from university lecturers to undergraduate students [11]. Team members help prepare and setup our events, maintain our website, provide administrative support, create craft objects, train festival volunteers, work on the craft stations at festivals, and occasionally run smaller events. We also benefit from the guidance of our small advisory board.

Venues

Holding events at universities can be a barrier to those who already feel intimidated by academic environments. Our philosophy is to remove as many barriers to participation as possible, so we avoid using university premises for our events and instead choose to hold our festivals in community hubs such as museums and civic heritage buildings. Such venues also lend our events both credibility and visibility, which help with increasing visitor numbers and securing sponsorship. To date, we have worked with The Auckland War Memorial Museum, The Otago Museum in Dunedin, The Teece Museum of Classical Antiquities in Christchurch, and The Great Hall at The Arts Centre in Christchurch.

Funding

Maths Craft New Zealand rely entirely on grants and sponsorship for funding. To date, we have secured over NZ$275,000 in grants, sponsorship, and in-kind support. Approximately NZ$150,000 of this comes from two government grants from the *Unlocking Curious Minds* fund, whose focus is on engaging young New Zealanders with science and technology. Our list of sponsors is available on our website [10], and includes universities, research centres, learned societies, government agencies, and charitable foundations. The in-kind support includes waived venue costs, venue staff time, equipment use, and printing services, and comes from universities, research centres, and museums. It also includes administrative support and some teaching relief for the two authors of this paper. All of this means that we are able to remove financial barriers for participants by keeping Maths Craft events free and open to everyone.

Feedback

Maths Craft New Zealand constantly evolves in response to feedback. This means that one of our priorities is to survey participants at all of our events. We're particularly interested in people's attitudes towards mathematics before and after participating in a festival, as this helps us to see if our approach is working and to check that we are reaching as broad a range of people as possible.
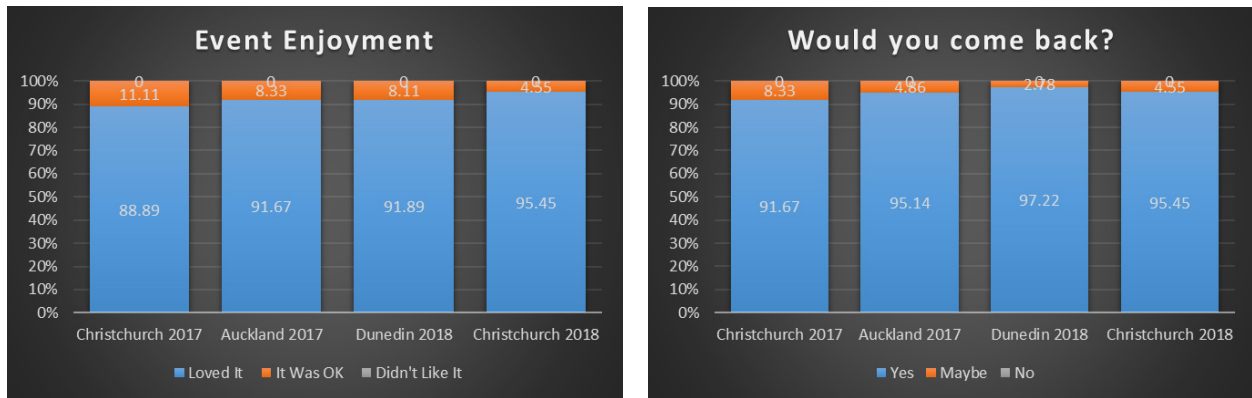
Figure 8: *Survey responses from the four most recent Maths Craft festivals.*

The responses to our festival surveys have been overwhelmingly positive. Consider for example the survey responses from our largest event to date, the 2017 Maths Craft Festival, a two-day event attended by around 3,400 people. Remarkably, 100% of the 109 survey respondents had a positive view of the Festival, with 92% saying that they "loved it". Over 94% said that they learned something new at the Festival, and 95% said they would "definitely" do something like it again. Most gratifying of all, the percentage of respondents saying that they like maths jumped from 59% before the Festival to 88% after it, with no-one on our exit survey indicating that they "don't like maths". Text responses indicate an increased recognition of the ubiquity of maths and mathematical thinking in everyday life, and also show our broad appeal. These comments include: "What a great event, our whole family has enjoyed it, from age 7–47!" Aside from experiencing the "fascinating complexity and depth to all of the various constructions", people were "amazed by how much breadth mathematics encompasses," and have now come to realise that "Fractals are EVERYWHERE" and "Geometry is way cool." And perhaps most heartening of all, that "Maths is exciting" and "maths can be fun!"
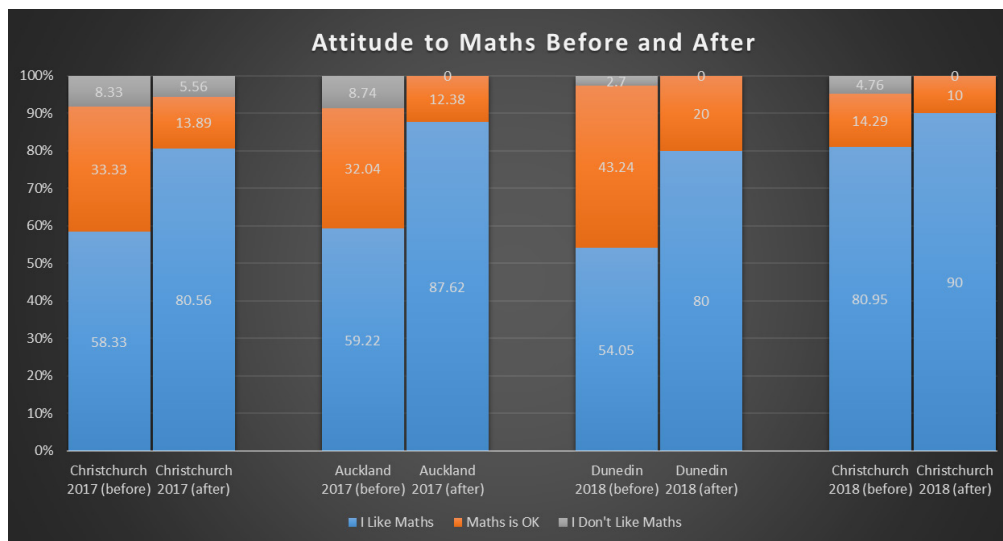
Figure 9: *Survey responses from the four most recent Maths Craft festivals.*

Figures 8 and 9 show data from participant surveys for our four most recent Maths Craft festivals. These are three examples of metrics we are particularly interested in: how much people enjoyed the festival, whether they would come again, and their attitude to maths before and after participating in the festival. In all three cases the responses are extremely positive. Around 90% of respondents at all festivals said that they "loved it", and no respondent at any festival said that they "didn't like it" (Figure 8, left). It is possible

for people to love a festival but not want to repeat the experience, so we were pleased that between 92% and 97% of respondents said that they would come back (Figure 8, right), with none of them saying that they would not. Finally, and perhaps most hearteningly, we saw positive shifts in attitudes to mathematics (Figure 9). At all four of these festivals, more people liked maths after the event than before, with no-one saying they disliked maths after the three most recent of our festivals, and much reduced percentages of people having a neutral or negative opinion of maths after all of our events.

The Road Goes Ever On and On

Over the past three years, Maths Craft have run numerous festivals and workshops across New Zealand, and have reached over 10,000 people. We are the country's largest maths outreach programme, and we are always looking for ways to expand and extend our reach. As well as continuing our festivals in cities around the country, we also want to run festivals in smaller, more remote towns, as these typically have little access to science outreach activities; our first such event is planned for May 2019. We recently began research into the efficacy of the Maths Craft approach, in collaboration with science communication and education experts.We also plan to write a Maths Craft book, take Maths Craft into prisons, run science communication training for young scientists and mathematicians, set up Maths Craft in a Box for distribution to schools, make a short film, run more teacher training, supervise PhD projects into the effectiveness of our approach, and create instructional videos for our website. Through our festivals and workshops, we are slowly changing the public perception of mathematics in New Zealand, but there is still a lot to be done and more adventures to be had.

References

[1]   C.C. Adams. *The Knot Book.* American Mathematical Society, 2004.

[2]   S. Barr. *Experiments in Topology.* Dover, 1989.

[3]   J.H. Conway, H. Burgiel, and C. Goodman-Strauss. *The Symmetries of Things.* AK Peters, 2008.

[4]   M. Gardner. "Flexagons." *Scientific American*, vol. 195, no. 6, 1956, pp. 162–168.

[5]   M. Gardner. "Mathematical Games: Six Sensational Discoveries That Somehow or Another Have Escaped Public Attention." *Scientific American*, vol. 232, no. 4, 1975, pp. 127–131.

[6]   T. Hull. *Project Origami: Activities for Exploring Mathematics.* CRC Press, 2013.

[7]   R.J. Lang. *Origami Design Secrets: Mathematical Methods for an Ancient Art.* CRC Press, 2011.

[8]   Maths Craft New Zealand Events. http://www.mathscraftnz.org/events/.

[9]   Maths Craft New Zealand Resources. http://www.mathscraftnz.org/resources/.

[10] Maths Craft New Zealand Sponsors. http://www.mathscraftnz.org/sponsors/.

[11] Maths Craft New Zealand Team. http://www.mathscraftnz.org/the-team/.

[12] MegaMenger. http://megamenger.com.

[13] D. Mitchell. *Mathematical Origami: Geometrical Shapes by Paper Folding.* Tarquin Publications, 2015.

[14] D. Taimiņa. *Crocheting Adventures with Hyperbolic Planes.* CRC Press, Second Edition, 2018.

[15] L.S. Penrose and R. Penrose. "Impossible Objects: A Special Type of Visual Illusion." *British Journal of Psychology*, vol. 49, 1958, pp. 31-33.

[16] R. Penrose. "Pentaplexity: A Class of Non-Periodic Tilings of the Plane." *The Mathematical Intelligencer*, vol. 2, no. 1, 1979, pp. 32-37.

[17] C.A. Pickover. *The Möbius Strip.* Thunder's Mouth Press, 2006.

[18] N. Robinson. *Fantastic Flexagons.* Hourglass Press, 2017.

[19] TVNZ One News 2016. https://www.tvnz.co.nz/one-news/new-zealand/maths-and-craft-combine-auckland-festival.

[20] TVNZ One News 2017. https://www.tvnz.co.nz/one-news/new-zealand/bringing-maths-masses-in-craft-day.