Bridges and Artists

Paul Gailiunas

25 Hedley Terrace, Gosforth, Newcastle, NE3 1DP, England; paulgailiunas@yahoo.co.uk

Abstract

Bridges has developed over two decades to become the leading international conference on mathematics and the arts. In many ways it has exceeded early expectations, but the primary aim of bringing mathematicians and artists together in a shared enterprise is hardly any nearer now than it was at the beginning. The obstacles to achieving this aim are significant, and will be overcome only by focused determination, and a belief that it is still important.

Beginnings

There is an original inside me.

What's here is a mirror for that, for you.

This quotation at the head of the preface of the first ever volume of Bridges Proceedings (1998) [27], taken from the Persian poet, Rumi, reflects the Neoplatonic thinking that runs through the text that follows. Its opening sentence expresses the belief that there are common characteristics underlying disparate disciplines, and the aim of the Bridges project is to make them explicit:

> A major reason for developing the Bridges Conference and this collection of papers is our desire to come together from a diverse set of apparently separated disciplines, to share and recognize abstract similarities, common patterns, and underlying characteristics.

A later paragraph presents a clear statement of the original motivation for Bridges, and provides another criterion by which later conferences might be judged:

> We hope the annual Bridges Conference and these proceedings have the potential to connect many more areas of intellectual pursuit, within a variety of disciplines in science, art, and humanities.

The same hope is repeated in the prefaces to the Proceedings of the next four conferences (1999-2002).

Historical Background

Many of the recurring themes at Bridges Conferences relate to important movements in the history of ideas, and a brief summary of this wider context will inform the later discussion.

Although we can see mathematical aspects in art from the earliest times, mathematics did not really exist as a separate category of thought, and even early medieval examples (such as Celtic or Islamic art) do not reflect an attempt to bridge any perceived divide. In the European Renaissance, when ancient Greek texts (and Platonism) became influential, a mathematical approach was consciously adopted, for example by artists such as Piero della Francesca [18]: a development to which the preface to the Bridges Proceedings for 2005 [32] alludes, commenting that even at this date there was no separation that needed to be bridged:

> Mathematics has periodically been employed not only to interpret and analyse art and architecture, but also to directly integrate with artistic products. During

> the European Renaissance, art, mathematics, architecture, science, and music flourished side by side. This is no longer the case, and although many artists and scientists are calling for ways to regain the lost mutual understanding, appreciation, and exchange, it has been hard to know how to create environments in which this can happen in a meaningful way.

By its nature architecture has always involved measurement and mathematics. Concern with proportion goes back at least as far as Vitruvius (born c. 80–70 BC, died after c. 15 BC), and his insistence on whole number ratios continued through Palladio (1508–1580) well into the nineteenth century. By the time of the scientific revolution in the seventeenth century the latest developments in mathematics were being consciously incorporated into architectural practice [11, 16].

The age of Romanticism at the beginning of the nineteenth century is probably the first time that efforts were made to connect disciplines seen as separate. In the UK, for example, David Ramsay Hay between 1842 [14] and 1856 [15] published a series of books presenting a theory of harmony linking colour, form, music and proportion. In Germany the influence of Idealism and particularly *Naturphilosophie*, with its emphasis on fundamental organizing principles led, for example, to Zeising and Fechner's ideas about the golden ratio, which became influential in the twentieth century [10].

The early twentieth century saw movements in the world of art that set out to break with tradition and find new means of expression. Some, such as Dada, embraced the irrational, but others, Futurism for example, celebrated the new developments in science and engineering [22]. Among these Bauhaus has probably had more influence on links between art and mathematics than any other single movement in the twentieth century. One account [7] comments:

> In order to discover such laws [governing spatial composition], intuition had to be combined with mathematics, real and transcendental laws; a constant interchange was needed between the individual and the cosmos. These esoteric theories belonged to the major themes of the early Bauhaus. We will encounter them again in the teachings of Klee, Kandinsky and Schlemmer.

While this clearly reflects the influence of German Romanticism, in the work of Max Bill, who had been a student at the Bauhaus, the mathematics is explicit, and there is little hint of mysticism [3].

In the middle of the century there was considerable interest in exploring the relationship between art and science (which was usually taken as including mathematics). Martin Johnson's *Art and Scientific Thought* is subtitled “historical studies towards a modern revision of their antagonism”. His position is summarized in the introduction [17]:

> It will require a mutual realization of likenesses and differences between the logical and the imaginative in our response to human environment. A tentative approach to such problems is offered in the present thesis that the sciences and even the most fantastic arts are essentially essays in Communication of Pattern, Form, or Structure of mental images.

Johnson is described as “a Doctor of Science” on the dust-wrapper. Naum Gabo's A.W.Mellon lectures in 1959 [9] consider the same issues from the point of view of an artist. A decade later C.H.Waddington (professor of genetics at the University of Edinburgh) published an account of the modern movements in art from a scientific point of view [38].

In the late 1960s and early 1970s there was a flowering of interest in geometric art and mathematics: Constructivism, which had its beginnings at the end of the previous century, was inspiring a new generation of artists [25]; Buckminster Fuller, who had been working since the twenties, came to worldwide prominence, especially after designing the US pavilion for Expo 67 in Montreal; the journal

Leonardo was founded by Frank Malina in 1968; although there had been earlier exhibitions devoted to computer art, Cybernetic Serendipity at the Institute of Contemporary Art in London in 1968 was particularly influential [24]; following a successful exhibition at the Institute of Contemporary Art in London (Exploration of Islamic Abstract Pattern and Design, 12-28 November, 1971) Paul Keeler led the organization of the World of Islam Festival in 1976 which generated a renewed interest in Islamic art.

Arthur Loeb has pointed out the Neoplatonic character of Fuller's thinking [20], and Fuller's adoption by the 1960s counter-culture is hardly surprising:

> … Fuller is a transcendentalist: he discerns patterns and accepts their significance on faith. His is not the burden of proof: the pattern is assumed significant unless proven otherwise.

Although the official publications of the 1976 festival do not emphasize Neoplatonism (unlike Critchlow's *Islamic Patterns*, published to coincide with it [6]) they cannot avoid it entirely, for example [4]:

> Now the geometric models used in traditional art have nothing to do with a rational, or even a rationalistic, systematization of art; they derive from a geometry which is a priori non-quantitative and which is itself creative because it is linked to data inhering directly in the mind.

The *Frontiers of Chaos* exhibition which was displayed in 25 locations in UK, USA, Canada, France, Belgium and Brazil in 1985, followed by the publication of *The Beauty of Fractals* [23], was the beginning of a period of wide public interest in mathematics and computer-generated art, but by the end of the century fashions had moved on. A few artists, mainly sculptors, continued to be interested in geometry, for example Tony Cragg [5], and Olafur Eliasson [37] whose team included Einar Thorsteinn, an architect much influenced by Buckminster Fuller [36], but they seem to be exceptions.

What Are the Aims of Bridges Conferences?

The opening paragraph of the "About Bridges" page on its website states the current aims and aspirations of the organization:

> The goal of the Bridges Organization is to foster research, practice, and new interest in mathematical connections to art, music, architecture, education and culture. All too often, mathematics can seem disconnected from or even antithetical to these other topics. We believe that mathematics and art can inform and enrich each other, that there are great ideas waiting to be found in mathematical analysis and synthesis of art, and that artistic thinking and activities can enliven the mathematics classroom.

Although the opening of the third sentence suggests a symmetrical relationship, interchanging "mathematics" and "art" would imply different priorities:

> The goal of the Bridges Organization is to foster research, practice, and new interest in artistic connections to mathematics, music, architecture, education and culture. All too often, art can seem disconnected from or even antithetical to these other topics. We believe that art and mathematics can inform and enrich each other, that there are great ideas waiting to be found in artistic analysis and synthesis of mathematics, and that mathematical thinking and activities can enliven the art classroom.

The original statement suggests that Bridges Conferences are a forum for mathematicians interested in art, music, architecture, and culture, and mathematics educators. Putting aside the fact that art does not

seem disconnected from music and architecture, the revised statement at first sight might seem nothing more than a change of emphasis. Certainly mathematics educators have run courses for artists [12], and in some countries integrated lessons in school are expected [13] but I do not recall any reports of an art teacher running a course for mathematicians. Similarly the "artistic analysis and synthesis of mathematics" is difficult to imagine, and it is unlikely that the Program Committee would accept an artist's analysis of an aspect of mathematics (although it has happened [33]).

Different people at different times will almost certainly hold differing views about the purposes of Bridges Conferences, and, although they were never intended to be official statements of policy, the prefaces to the Proceedings are the best evidence available of the aspirations that prevailed at various times during the twenty years of the conference's existence. The statement that currently tells the world about the goal of the Bridges Organization is in marked contrast to aims expressed in the first five years:
1998 quoted earlier.
1999: There is a hunger for this gathering and dialogue among disciplines, and we are delighted that we can provide a home for this critical discussion of science, mathematics, and the arts [28].
2000: Michele Emmer, one of the first to call for a gathering of mathematicians and artists under one roof, clearly emphasizes the need for this merging of forces in his paper in this current volume [29].
2001: We continue our efforts to integrate the disciplines of mathematics, art, science, and music [30].
2002: We too shall continue to seek the connecting spheres and form the bridges that will join us and, in that joining--anchor us [31].

While interdisciplinary research has become more common in the twenty-first century it has tended to be in the social sciences [e.g. 2], or in approaches to technical problems that draw on disparate scientific disciplines [e.g. 1], although there is now a growing interest in collaborations between artists and craftspeople and experimental scientists [19]. Much that is presented at Bridges Conferences seems to be related more to the mid-twentieth century movements already described than to more modern developments, with the exception of recent educational initiatives, particularly in the US, generally known by the acronym STEAM (science, technology, engineering, art, and mathematics).

In summary, the Bridges Conference has had various stated aims at different times:

- to share and recognize abstract similarities, common patterns, and underlying characteristics
- to provide a home for the critical discussion of science, mathematics, and the arts
- to foster research, practice, and new interest in mathematical connections to art, music, architecture, education and culture
- to provide teachers of mathematics with new ideas and methods for conveying the beauty, relevance, and ubiquity of mathematical ideas.

How Well Is It Succeeding?

What I have termed the Neoplatonic position, summarized as the belief that similarities, common patterns and underlying characteristics in mathematics and art already exist in some abstract sense, presents difficulties: it is not very useful as a criterion to judge the success of Bridges Conferences since anything that has been presented will express some relationship, and it encourages an enthusiasm that can easily "discover" connections that are illusory. On the other hand, as outlined above, Neoplatonism has influenced Islam, the European Renaissance, theories of proportion, and the counter-culture of the 1960s (through the constructions of Buckminster Fuller and Steve Baer, for example). Art produced in or influenced by these contexts is likely to have a mathematical aspect, and it would be appropriate for presentation at a Bridges Conference, although the submission could include an uncritical acceptance of, or creation of, misconceptions, especially if written by an artist with little background in mathematics.

John Sharp, one of the editors that year, tried to address these problems in the front matter of the Bridges Proceedings 2006 [34], where he urges the Program Committee to be tolerant of non-mathematicians in order to support the aim of encouraging dialogue among disciplines:

> Authors have been very accommodating in this respect and in some cases produced papers which are excellent examples of building the kind of bridges that the conference is aiming at. There are papers here which might have been more suitable for a pure mathematics conference. There are papers which mathematical readers will find incorrect or even confused and we do not have the luxury of many iterations to get a paper correct; with a journal this can take years and we only have a couple of months. Mathematicians can be very polarized (binary) in their outlook and often intolerant of what does not conform to the rigour of their subject. So if you are reading with a supercritical eye remember that an artist is not necessarily a mathematician and vice versa. Before being too critical ask yourself if the author has seen something that you haven't.

Submissions to the early conferences included three or four papers each year that discussed connections between mathematics and art in general, and some addressed the associated problems, for example [21]. A few are still submitted occasionally. The aim of fostering dialogue between mathematicians and artists, articulated in the prefaces to the early Proceedings, is the most ambitious one that can be identified among the various statements, and it is where Bridges Conferences could make a unique contribution. The natural tendency for groups to develop an unconscious acceptance of particular points of view, and actively exclude dissent is well known. The only cure for such "silo mentality" is to encourage differences, and Bridges Conferences aim to do this, but there are further difficulties beyond those already considered. For the most part the two cultures (to use C.P. Snow's phrase [35]) simply do not understand each other: artists are not usually concerned with mathematical rigour. When they talk about their work it is in relation to wider contexts, such as the art world and general culture, seldom mathematics. Generally mathematicians, who have been trained to spot any gap in the train of an argument, and also to computer scientists, who are used to any slight logical imprecision being punished by a software crash, find their statements annoying or incomprehensible. The incomprehension might be deliberately provoked by some artists, who in any case probably do not see the mathematics community as their main audience. Of course there are exceptions, most notably in movements such as Cubism and Constructivism, which included mathematical and scientific developments as a stimulus for creativity, but Modernism has been out of fashion for some time, with the result that there are only a few artists now who might be interested in participating in a dialogue.

Despite the problems, an analysis of the data in tables 1 and 2 (supplementary material) shows that there has been some success. About 10-20% of the papers presented every year are by people who identify themselves as artists, although some caution is needed in interpreting this number since many actually have a mathematical background and art is more or less a hobby for them; a suitable description might be "mathematician turned artist". For example of the nine submissions in 2017 (not counting collaborations) by people who either described themselves as, or seemed to be, artists, one appears as a computer scientist in earlier Bridges Proceedings, a web search identifies three of them as having a mathematical background, and I know personally that one used to be an engineer. With the same caveat, the number of papers that represent collaboration between individuals from different disciplines also indicates some success. Ignoring collaborations between mathematicians and/or computer scientists, after the first five years when there were very few, usually between 10-20% of the papers presented have joint

authorship spanning different disciplines. About 25% of papers presented in 2008 (Leeuwarden) and 2017 (Waterloo) are collaborations across subject boundaries. Actual dialogue that occurs during conferences by its nature goes unrecorded (unless it happens to lead to a submission), and some papers by a single author might involve joint work, so the statistics probably underestimate the actual level of collaboration.

In addition the art exhibition includes pieces by artists who have not submitted papers but, since (apart from 2009) the Catalog does not give affiliations, it is not possible to separate them from mathematicians or computer scientists who happen to have an interest in art. Table 3 (supplementary material) shows the total number of artists (or collaborations) included in the Catalog, which has increased steadily from 2009 apart from 2014 (Seoul) and 2017 (Waterloo).

The website statement already discussed presents fewer difficulties, and is actually a more accurate reflection of reality: right from the beginning 30-50% of papers have been by authors who can be identified as mathematicians or computer scientists, and this is almost certainly an underestimate since, as discussed earlier, many who give no affiliation or identify themselves as artists actually have a mathematical background. To some extent the material presented at Bridges Conferences represents one side of a long-running difference of opinion within mathematics and mathematics education about the validity of visualization, which was at its most extreme around the middle of the twentieth century. The characterization of H.S.M. Coxeter as “the man who saved geometry” indicates how far things had gone [26, especially pp. 150-170], and it is not surprising that Bridges 2005, with the support of the Canadian Mathematical Society, included a whole day devoted to his memory. The increased availability of computers from the 1980s, and the popularization of once esoteric concepts such as fractals (more technically geometrical objects with non-integral Hausdorff dimension) and chaos, added weight to the reaction against the trend towards greater abstraction. Predictably these topics have been some of the more popular ones at Bridges Conferences, where the products are usually considered to be art, although few artists would see them as such.

That is not to say that the conflict is resolved. In fact many members of mathematics departments in universities and schools disparage physical apparatus and visual imagery, and emphasize the value of pure abstraction. I know from personal experience how, for some, physical teaching aids are simply toys and appropriate only in elementary education, if at all. If a visual approach is to become more accepted in such contexts it matters that the credibility of conferences such as Bridges is not damaged by the inclusion of material that could provide ammunition for its opponents. For reasons already considered, this requirement can present a barrier to dialogue among disciplines.

Although it is seldom mentioned in the prefaces (the fourth bullet point above is based on a statement in the 2005 Proceedings [32]) the provision of resources for schoolteachers was always an element of Bridges Conferences, although technically “teachers’ day” was after the end of the conference in the first few years. More formal educational submissions were first included in the Proceedings in 2005 (Bridges for Teachers, Teachers for Bridges, known as Workshops from 2009), and by 2011 the number of Workshop submissions justified a complete track in the schedule. In fact a workshop might not be specifically for teachers, and many are practical sessions with no educational objective. Papers with explicit pedagogical content, whether Workshops or not, have accounted on occasion for up to 23% (in Jyväskylä) of the total number of submissions, although the proportion is more usually just over 10%.

A related aspect since 2006 has been the inclusion of Family Day, at which a range of activities is presented to engage the public in general, and children in particular, in mathematics in ways that are easily accessible.

Conclusion

Twenty volumes of Proceedings account for 1700 papers (including abstracts) that have been presented at Bridges Conferences. Taken with the several additional activities (film night, poetry day, family day, informal music night, formal music night, and so on) that have been introduced over the years it would be difficult to conclude that the conferences have been anything other than successful, although it is difficult to judge how much influence they have had beyond those who have attended them. On the other hand I believe that the aspiration expressed in the prefaces of the first five years of Proceedings, "to come together from a diverse set of apparently separated disciplines" [27], is far from fully realized. Perhaps the early optimism was unjustified, and some of the difficulties considered earlier really are insurmountable.

The very success of the Bridges Conference might have caused further problems: it has become the largest conference in the world for what is in effect a separate mathematics-arts discipline. There is undoubtedly a Bridges Community and, having attended every Bridges Conference since 2000 and contributed in various ways (mainly on the Program committee, in particular as a Workshop Coordinator) I must count myself among its members. This community is more outward looking than most, but like any group it has developed its own norms and shared understandings. In particular there appears to be a strong belief that mathematics-arts is the bridge between mathematics and the arts, whereas I believe it would be more accurate to recognize it as a discipline in its own right. If it is the bridge then the early aspirations have been realized; if it is a separate discipline two bridges are needed: to mathematics and to the arts. A paper on a work of art, written by a mathematician, is not the same as a dialogue between an artist and a mathematician. If it is enough that the paper makes a contribution to mathematics-arts then the difficulties likely to accompany real dialogue (different cultural assumptions, different motivations, different values, and so on) are avoided, and any motivation there might have been to seek dialogue is dissipated.

There might be another factor: Bridges Conferences now have an established identity, and interested people are likely to have ideas about who it is for and what type of material will be presented (and they could be mistaken). Some of them might conclude that it is not for them. When Bridges Conferences were largely unknown they could seem more open to possibilities, and such self-selection, or rather self-exclusion, was less likely.

Mathematicians with any interest in the arts usually talk about it with confidence while most artists are very quick to say that they know little or nothing about mathematics. Given this imbalance, artists are likely to be comfortable at Bridges Conferences only if mathematicians take the initiative and actively encourage them to attend, perhaps show a little humility and admit that they are not specialists in art, and ask, as John Sharp advised, whether artists have seen something that they haven't.

References

[1] https://www.manchester.ac.uk/research/structure/interdisciplinary/ accessed December 2018.

[2] http://oakland.edu/ais/publications/ accessed December 2018.

[3] M. Bill. *Max Bill* (exhibition catalogue). Albright-Knox Art Gallery, 1974.

[4] T. Burckhardt in I. El-Said, A. Parman. *Geometric Concepts in Islamic Art*, London, 1976, p. ix.

[5] T. Cragg. *Unnatural Selection*. Hirmer, 2016.

[6] K. Critchlow. *Islamic Patterns*, Thames and Hudson, 1976.

[7] M. Droste. *bauhaus* 1919-1933, Benedikt Taschen, 1990, p. 44.

[8] K. Fenyvesi. Bridges: A World Community for Mathematical Art, *Math. Intelligencer* 38, 2016, 2, pp. 35-45.

[9] N. Gabo. *Of Divers Arts*, Pantheon Books, 1962.

[10] P. Gailiunas. The Golden Spiral: The Genesis of a Misunderstanding, *Proceedings of Bridges 2015*: *Mathematics, Music, Art, Architecture, Culture*, Tessellations Publishing, 2015.

[11] G. Gerbino, S. Johnson. *Compass and Rule*, Yale University Press, 2009.

[12] J. Griffiths. Art by numbers: a collaboration between an Art and Maths Department, *Journal of Mathematics and the Arts*, vol. 3, iss. 3, 2009, pp. 155-170.

[13] M. Havinga, P. Portaankorva-Koivisto. Visual Arts and Mathematics Education: Looking for Integrative Phenomena*, Proceedings of Bridges 2016,* Tessellations Publishing, 2016, pp. 79-86.

[14] D. R. Hay. *The Natural Principles and Analogy of the Harmony of Form*, Edinburgh, 1842.

[15] D. R. Hay. *The Science of Beauty: as developed in Applied Art and Nature*, Edinburgh, 1856.

[16] G. L. Hersey. *Architecture and Geometry in the Age of the Baroque*, University of Chicago Press, 2000.

[17] M. Johnson. *Art and Scientific Thought*, Faber and Faber, 1944, p. 11.

[18] M. Kemp. *Behind the Picture*, Yale University Press, 1997, pp. 97-100.

[19] R. Kneebone, C. Schlegel, A. Spivey. Science in hand: how art and craft can boost reproducibility, *Nature*, Vol. 564, 2018, pp. 188-189.

[20] A. L. Loeb in R. B. Fuller. *Synergetics*, 1975, paperback edition Macmillan, 1982, p. xv.

[21] S. Marcus. The Art-Science Marriage, From Quarrel to Understanding, *Bridges Conference*, 1999, pp. 279-290.

[22] F. T. Marinetti. *I Manifesti del Futurismo*, Florence 1914, English translation in J.C.Taylor. *Futurism*, New York, 1961, online at http://bactra.org/T4PM/futurist-manifesto.html (accessed December 2018).

[23] H. -O. Peitgen, P.H.Richter. *The Beauty of Fractals*, Springer-Verlag, 1985.

[24] J. Reichardt. *Cybernetic Serendipity*, Studio International, 1968.

[25] G. Rickey. *Constructivism Origins and Evolution*, George Braziller, 1967.

[26] S. Roberts. *King of Infinite Space: Donald Coxeter, The Man Who Saved Geometry*, Walker & Company, 2006.

[27] R. Sarhangi. Preface, *Bridges Proceedings*, Bridges, 1998, p. ix.

[28] R. Sarhangi. Preface, *Bridges Proceedings*, Bridges Conference, 1999, pp. ix-x.

[29] R. Sarhangi. Preface, *Bridges Proceedings*, Bridges Conference, 2000, pp. ix-x.

[30] R. Sarhangi. Preface, *Bridges Proceedings*, Bridges Conference, 2001, pp. ix-x.

[31] R. Sarhangi. Preface, *Bridges Proceedings*, Bridges Conference, 2002, pp. ix-x.

[32] R. Sarhangi. Preface, *Bridges Proceedings*, Bridges Conference, 2005, pp. ix-x.

[33] J. Saxon-Szasz. The "Dual Nature" of the Point, *Proceedings of Bridges 2016*, Tessellations Publishing, 2016, pp. 595-596.

[34] J. Sharp. *How Bridges Proceedings* come together in *Bridges London*, Tarquin Publications, 2006.

[35] C. P. Snow. *The Two Cultures and the Scientific Revolution*, Cambridge University Press, 1959.

[36] E. Thorsteinn, O. Eliasson. *to the inhabitants of space in general and the spacial inhabitants in particular*, Bawag Foundation, 2002.

[37] P. Ursprung. *Studio Olafur Eliasson*, Taschen, 2012.

[38] C. H. Waddington. *Behind Appearance*, Edinburgh University Press, 1969.