M-u-l-t-i-p-l-i-c-i-t-y
Princeton University
February 2, 2021

--

1.

Around 1736, Swiss mathematician Leonhard Euler described a geometry of connections in a paper of numbered assertions. The first goes like this:

> 1. THE branch of geometry that deals with magnitudes has been zealously studied throughout the past, but there is another branch that has been almost unknown up to now; Leibnitz spoke of it first, calling it the "geometry of position" (geometria situs). This branch of geometry deals with relations dependent on position alone, and investigates the properties of position; it does not take magnitudes into consideration, nor does it involve calculation with quantities. But as yet no satisfactory definition has been given of the problems that belong to this geometry of position or of the method to be used in solving them. Recently there was announced a problem that, while it certainly seemed to belong to geometry, was nevertheless so designed that it did not call for the determination of a magnitude, nor could it be solved by quantitative calculation; consequently I did not hesitate to assign it to the geometry of position, especially since the solution required only the consideration of position, calculation being of no use. In this paper I shall give an account of the method that I discovered for solving this type of problem, which may serve as an example of the geometry of position.

225 years later, designers Ray and Charles Eames unpacked this "geometry of connections," or topology, in their first exhibition designed and produced to inaugurate the California Museum of Science and Industry. "Mathematica" was an exhibition about mathematics for a mass and diverse audience. It was originated by the Eames Office following an invitation to propose an appropriate exhibition for the new museum.

Ray [↑] described what they meant to do in an interview with the Library of Congress from 1980:

> Yes. The whole purpose of that show was "Lifting the corner of the tent" to let people know the pleasure and the joy that mathematicians had in their work. So when you see the workings of any of those things – the soap bubble – it reflects the terrific joy that was originally felt in the discovery of that model, or in the use of models, the use of thinking, and the result of observation and relationships in observation, and relationships of knowing what someone did and someone didn't do. The chart shows how different people were influenced by different things, things happening because of other things, as a result of other things happening, things in the past happening, things coming together at the right time – all those layers of happenings.

Mathematica used hands-on mathematical models, extensive graphics, visual demonstrations, and even a collection of two-minute films designed for one viewer at a time, to address a collection of areas of contemporary mathematics. One of these was topology.

2.

Returning to Euler, the second paragraph lays out his particular problem:

> 2. The problem, which I understand is quite well known, is stated as follows: In the town of Königsberg in Prussia there is an island A, called "Kneiphof," with the two branches of the river (Pregel) flowing around it, as shown in Figure 1. There are seven bridges, a, b, c, d, e, f and g, crossing the two branches. The question is whether a person can plan a walk in such a way that he will cross each of these bridges once but not more than once. I was told that while some denied the possibility of doing this and others were in doubt, there were none who maintained that it was actually possible. On the basis of the above I formulated the following very general problem for myself: Given any configuration of the river and the branches into which it may divide, as well as any number of bridges, to determine whether or not it is possible to cross each bridge exactly once.

Schematically, the setup looks like this [diagram].

The Seven Bridges of Königsberg is a widely known problem in mathematics and foundational for Topology. Meanwhile in the intervening years, what was Königsberg is now Kaliningrad; two bridges were bombed in World War II (later rebuilt); and two more were removed to make room for a highway. The Seven Bridges of Königsberg are now The Five Bridges of Kaliningrad.

This will be a class about *how things change* and *what stays the same when they do.* It will be a class about the overlaps between two (perhaps) seemingly divergent fields, Topology and Graphic Design. We will look at one from the point of view of the other and hopefully we will discover what

Graphic Design might offer to Topology, and conversely, why Topology may be important to Graphic Design, particularly now.

We will look at bridges, knots, dancers, snowflakes, inside-out spheres, fonts, space-filling curves, maps, string figures, and multi-character storylines, and we will ask in each case, given the multiple examples, what do they have in common? What does *not* change? Exactly how are they fundamentally connected? The Eames' meta-thesis on design, repeated in numerous forms over the years, will be good to keep in mind:

> Eventually everything connects – people, ideas, objects ... the quality of the connections is the key to quality per se.

In the exhibition catalog Connections: The Work of Charles and Ray Eames, design critic Ralph Caplan follows this thought:

> Nothing they or anyone else has ever said or written comes closer than that to the heart of the work, and thinking, and convictions. And nothing anyone has ever said or written comes closer to describing the pattern of the Eames design practice, which might be defined as the art of solving problems by making connections.
>
> Connections between what? Between such disparate materials as wood and steel, between such seemingly alien disciplines as physics and painting, between clowns and mathematical concepts, between people–architects and mathematicians and poets and philosophers and corporate executives. Eames designs are anything but ambiguous. They are characterized by the kind of clarity people looked to photography for when the art was new. This clarity is never confused with severity; there are no easy geometric solutions. Rather the designs have a quality of being “in focus” that may derive from the defensibility of each detail.

[Eames process slides]

The focus, clarity, precision, and seeming inevitability of an Eames design comes from their deep engagement with the subject matter. They learned much more about the subject at hand than was ever legible in the finished product. To this end, they often worked with experts. MIT physicist Philip Morrison was one. In the introduction to that same exhibition catalog, Morrison writes about this from his experiences working with the Eames:

> The good technician, engineer or scientist must work at depth, for he is disciplined by the thing itself. But he typically neglects to examine his work in search of beauty. He leaves the surfaces careless, the details slighted, the context taken for granted. The good designer does not make that set of errors, but he does not often enter the depths. His limits lie there: where he falls short, he is likely to remain superficial, his beauty a gloss, his comments graceful, but without penetration. It is the painstaking genius of the Eames Office to enter the depths of understanding and control, without once forgetting the eye of the beholder. Roots, blossom, and fruit: all three. In the narration he wrote and recorded himself for a film he and Ray made to explain a storage system they designed, Charles Eames says, “The details are not details. They make the product. The connections, the connections, the connections”

Starting in 1967 with the Commission on College Physics, Philip Morrison regularly worked with the Eames Office. They developed a mutually reinforcing relationship which carried on over a range of projects. Maybe the best known was a short educational film with a long title from 1977, “Powers of Ten: A Film Dealing with the Relative Size of Things in the Universe, and the Effect of Adding Another Zero.” Morrison collaborated on the content and even provided the voice-over.

[Powers of Ten]

This film, like most Eames projects, evolved. A first version from 1968 was called "A Rough Sketch for A Proposed Film Dealing with The Powers Of Ten and The Relative Size of Things in the Universe"

[Powers of Ten, Rough Sketch]

Asked by the Aluminum Company of America in 1957 to make something that demonstrates the use of their product, the Eames reponded with a solar-powered useless machine.

[Solar Do Nothing Machine]

3.

Meaanhile, back to Euler's numbered paragraphs where we’ve arrived at number three.

> 3. The particular problem of the seven bridges of Königsberg could be solved by carefully tabulating all possible paths, thereby ascertaining by inspection which of them, if any, met the requirement. This method of solution, however, is too tedious and too difficult because of the large number of possible combinations, and in other problems where many

> more bridges are involved it could not be used at all. When the analysis is undertaken in the manner just described it yields a great many details that are irrelevant to the problem; undoubtedly this is the reason the method is so onerous. Hence I discarded it and searched for another more restricted in its scope; namely, a method which would show only whether a journey satisfying the prescribed condition could in the first instance be discovered; such an approach, I believed, would be much simpler.

[exercise -- write out all possible paths]

Ray and Charles Eames were always interested in communicating process. They believed that showing how a result was produced was essentially generous, inviting the viewer in as a participant, and so then opening up what might otherwise be an opaque subject. Ralph Caplan continues:

> That concern became a major promise in 1953 when Charles and Ray collaborated with George Nelson and Alexander Girard in an educational experiment at the University of Georgia and at U.C.L.A. The experiment combined film (including three-screen projection) and exhibition techniques with sound and smell to explore the possibilities of technology in education.

A Rough Sketch for a Sample Lesson for a Hypothetical Course, 1957

> The promise was fulfilled in 1961 with the opening of “Mathematica: a world of numbers...and beyond,” an IBM-sponsored exhibition at the Museum of Science and Industry in Los Angeles.
>
> “Mathematica” brought together a large number of features that had come to characterize the Eameses’ work generally. It was loaded with detail, largely in the form of a massive “history wall” that related significant mathematical developments to each other and to other developments. It was participatory, not in the sense of having viewers activate mechanical exhibits by pressing buttons, but in the sense of having them perform operations that led to understanding. Most important of all, it was enjoyable. Or rather, most important of all was the way it was enjoyable. The idea that science can be fun had been advanced soberly by the textbook publishers in the forties and was most intensely seen in the Armed Services training films done by Walt Disney and various of his imitators. The fun was additive, either blatantly in the form of irrelevant jokes that actually served to distract, or subtly in the form of hypothetical problems thought to be amusing.
>
> But the Eames never set out to make science fun. They set out to help people experience the fun that is science. “Mathematica” may not really make mathematics easier, but it makes it clearer and the clarity permits the perception of elegance that mathematicians talk about and that few of us experience.
>
> The enjoyment in the exhibition is like the enjoyment mathematicians find in the subject, which is why mathematicians and small children can share the experience, and repeatedly too. The viewer of the Mathematics Peep Show film modules that support the show is not told about the concept of symmetry or even shown it, as with snowflake illustrations. Rather the viewer is brought charmingly into confrontation with the concept’s visual (and therefore literal) meaning and with its philosophical (and therefore mathematical) implications.

4.

Let’s return to Euler where he begins to describe the process that leads to his result. After this paragraph, Philip is going to lead us all through the problem.

> 4. My entire method rests on the appropriate and convenient way in which I denote the crossing of bridges, in that I use capital letters, A, B, C, D, to designate the various land areas that are separated from one another by the river. Thus when a person goes from area A to area B across bridge a or b, I denote this crossing by the letters AB, the first of which designates the area whence he came, the second the area where he arrives after crossing the bridge. If the traveller then crosses from B over bridge f into D, this crossing is denoted by the letters BD; the two crossings AB and BD performed in succession I denote simply by the three letters ABD, since the middle letter B designates the area into which the first crossing leads as well as the area out of which the second crossing leads.

(PO continues to unpack and explain the problem concisely including the general solution perhaps using the Zoom whiteboard if useful?)

Finally, let's return to the Eames Connection catalog where it describes their synthetic approach to learning and teaching. Again, Caplan:

The connections, the connections. It will in the end be these details that... give the product its life.

Again, Charles Eames talking about furniture. Again, the message applies equally to the work of the office as a whole. In the aluminum group chairs the seat pad’s two outer layers of fabric and an inner layer of plastic foam are combined through electronic welding. The entire seat pad is stretched across a two-sided die-cast aluminum frame that is cylindrical at top and bottom. The ends of the seat pad are turned up over the cylinders in each corner and held by tension. Supported by metal only at the corners and sides, the fabric seat is a slung bolt of softness juxtaposed against the elegant hardness of the frame. Both qualities are visible and palpable: end and means are equally discernible and almost indistinguishable from each other.

Their designs for play – The House of Cards, The Toy – are never prescriptive play products; they are invitations to connect. You (child or adult) accept the invitation at some risk. There will be difficulties, limits, pains as well as pleasures of discovery. (Life may be modular but it isn’t neat.) Things fall apart; the center will not hold until the parts are put together in a disciplined way. Because play is intrinsic to meaningful work, the toys are not separate. The earliest plywood furniture included children's furniture. The toys are objects for living and are not subordinate to other objects for living. They work.

The payoff in these toys is simply the understanding of payoff, the realization of rewards that are not immediate. To perceive that may be, in educational terms, to make the most important connection of all.

[Slides end, freeze on Ray Eames contemplating The Toy]

And the payoff is a connection. No arbitrary reward for good behavior, it is tied inextricably to the experience that generates it. This is why, when consulted by a Massachusetts Institute of Technology as to the best way to infuse their technologically heavy curriculum with art, Eames rejected the idea of additional art courses or fine arts programs as “an aesthetic vitamin concentrate” Instead he designed an alternative situation, a program for enriching the student’s (and the university’s) communicative capabilities to the point where they could experience the aesthetic possibilities of their own discipline.

The situation he designed had two essential parts. The first called for each academic department to include a unit of teaching assistants whose first allegiance was to the departmental discipline but who also were gifted and trained in film, graphics, and writing. Their responsibility was to produce packets of current information that would keep everyone within the department aware of what was going on. The best of the packets would be made available outside the department, and the best of those would be distributed outside the university.

Work done by these units was to be “insight motivated, arriving at as well as conveying insight)” thus precluding the creation of still another campus media center to prepare slides on demand from instructors who wished to beef up non-visual material. Not that no technical service center would be needed; clearly one would. But it would be designed to service the twenty-five or so professional units.

The beauty of the scheme is that it allows for the introduction of aesthetics as required for pleasure and communication, not just as another base to be touched before a student is home safe.

The second part would involve each student; for each, near the end of his M.I.T. career, would join one or two other students in teaching something of their major specialty to an elementary school class for a semester. The teaching could take the form of films, exhibits, lectures, games, models—whatever the team needed to make what they knew and understood meaningful to children. “...If the M.I.T. student is going to learn anything about art,” Eames argued, “he will learn it here.”

The entire design repudiates conventional approaches to the same goal. These mainly consist of three kinds of programs. One gives students massive doses of high art (no one gets a diploma without taking “appreciation” courses to guarantee that he has heard, if not listened to, Beethoven’s Ninth Symphony and looked at, if not seen, a Dutch Master or a reproduction of one). Another is an egalitarian attempt to “reach the student where he is” by running him through courses in rock and roll, horror movies, great graffiti of the sixties, etc. A third is the studio approach of encouraging the student to “do it himself” on the grounds that his “it” is as aesthetically valid as anyone else's.

(It may be, but it is not as aesthetically rewarding.) The Eames design calls for appreciation through the experience of searching out the aesthetic character of the student’s own discipline. It also includes another favorite Eames idea: the university as a found object, a collection of traditions and facilities already on hand that can be transformed by fresh perception.

*

Continues in class ...