Design and Construction—the Queen’s way?
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For 40 years I have been struggling with the question of how and what to teach. I think I have all the right ideas of what ought to happen (in teaching and learning) and I know my material well, and I talk quite a bit with my students, but somehow I’ve never been able to feel that I’m getting it right. Something important is missing, but I’ve had a lot of trouble figuring out what it might be.

To be sure I’ve tried to find something to blame: the text-books, the students, the exams, the culture… One thing I have never thought to blame is my subject, mathematics, as I know it to deliver an engaging narrative, a sophisticated structure and an indescribable beauty.

But it is this very beauty and structure, this narrative power that I seem to have so much trouble bringing effectively into my large first-year class.

Recently I have developed a better sense of the changes I need to make and my purpose here is to discuss some of those ideas. The ideas I will talk about are not new; they have been in the literature for more than 100 years.

Curriculum essentials.
What, as a teacher, am I to give my students? Certainly I want to try to give them my love of the subject and my thirst to learn. But more particularly, I would single out two complementary outcomes:

Creativity. There are many other words for this—imagination, innovation.
Critical thinking. Or more simply, perhaps, thinking clearly.

In the literature there are many variations on this complementarity:

synthesis and analysis
right brain and left brain
divergent and convergent thinking
conceptual and technical

artistic and artisan
design and construction
Romance and Precision (more on this at the end)

Design and construction
Over the last ten years or so, this one has interested me more and more. Too often I’m not quite sure how to get hold of creativity, or what exactly it is, but I do understand what it means to design a structure or a tool or a process. And for me, I am at my most creative when I am engaged in a design process. And then, to test the design, or to realize a piece of it or to think more clearly about it, I need to move into a more hands-on construction phase. In particular, in actually having to “build” a concrete realization, I am forced to think more clearly about my design.

Over many years I have spent considerable time working to find or invent tasks and problems that incorporate elements of design and construction. It is a challenge to find and tune such problems but I have enjoyed this process immensely. And I have felt strongly that my students need that experience as well. But as I have said, in practice I have found it difficult to incorporate such tasks into my courses, particularly in first year.

Why have I had so little success at this? Is it that the problems are too hard or too ambitious for the students? Is it that they are too wild, too ill-tempered, too unpredictable? Or is it that they don’t fit well enough into a demanding prescribed curriculum? Maybe all of the above are implicated. Anyway, somehow, I never seem to have enough time, and design and construction certainly take time.

Changing the architecture.
Imagine a building that is to be converted to a new use. It is old and has many wonderful features which you want to preserve, but your new objectives don’t seem to fit properly in that space. What you need is a good architect, a specialist in interior design.

That’s what I need—a good architect. My problem exactly is that I’ve been trying to put a new pedagogy into an old curriculum structure. And the traditional rather “linear” structure won’t provide the kind of interior space my new pedagogy requires.
I believe that, for the most part, this architect will begin by knocking down the walls of order and completeness that have always been taken to be essential features of a mathematics course. She will say, and I will find myself slowly nodding in agreement, that it’s simply not true that you can’t learn Y until you’ve learned X, that it’s simply not true that if you leave X out you cripple or handicap the students in their future lives. Those who believe that the traditional table of contents is sacred, she will exclaim, haven’t understood the difference between what is taught and what is learned. Indeed I well understand that students learn by filling in the gaps as they incorporate the fragments bit by bit into their world view. And those processes are the raw materials of design and construction.

I’m definitely not saying that we should throw order and logic out the window. I’m definitely not saying that the course canvas should be a jumble of shapes and colours. I’m saying rather that the organizing principles of the curriculum should be design and construction and that their artistic needs must come first.

And what does that principle gain me? I believe that it gives me the freedom to choose the very best that the subject has to offer. In fact we the teachers, in putting the curriculum together, are ourselves cast into the design/construction role, and become ourselves engaged in the very activity that we want to open up for our students. Here’s another way to put it. It allows us to replace a logical curriculum structure with a narrative curriculum structure. Art in the service of science.

This is a different approach. It needs to be emphasized that this is a new kind of curriculum. How the material is learned is different and to some extent what is learned will be different too. The traditional approach is “bottom up.” The student is given results, techniques and examples and then is asked to practice these and use them to solve problems which are applications or modest extensions of what has been learned. In the design/construction approach, the student is given tasks and problems that are more elevated, more mature, even more enticing and, with guidance from teachers, peers and other resources, learns how to break them down, take them apart, construct simpler more manageable tasks, create auxiliary problems to develop particular skills and progressively work towards a re-creation and understanding of the whole.

With this observation, I am starting to see that this curriculum model might just give me a way of teaching the very best mathematics, the math that I myself get excited about. This isn’t a question of material being too advanced for first year, it’s more about the size and sophistication of the problems I use to define the curriculum. I’m quite happy to stick with “first-year material,” but I want to work with problems that are imaginative, broad in scope and that require the student to drill down to expose the underlying structure.

But I must be prepared for the fact that many of my students will find this “lively” encounter with mathematics rather unwelcome. Their anxiety will alienate them from the chase, and it will take me some time, perhaps years, to find a way to give them the security that they need. But I must find a way to do that.

Not only my students, but also some of my colleagues will have serious reservations about this approach. Less material will be formally “covered,” and as part of that there will be ‘gaps.’ Of course there are already gaps in the students’ knowledge, but these are less visible than gaps in my teaching. I will need to consult with these colleagues, most particularly for my large service courses that prepare students for other programs.

This approach will need to be balanced with more traditional material. I believe that, for some students, the need to learn the basics is real. But I want to work with problems that are imaginative, broad in scope and that require the student to drill down to expose the underlying structure.

Technology.
For me, technology will play a key role in this curriculum transformation. I have started making brief (5 minute) videos of significant ideas and key examples in the course (in fact most of them are made by my senior students). The advantages of this resource have been much discussed:
--students can access them at any time
--and can choose the pace that is right for them
--and my time in class is freed to be spent in more interactive ways.

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My discussion here suggests an elaboration of the last point. The videos can offer an ordered refuge from the relative chaos of the investigative approach. They can in fact offer a version of a complete linear development of the material, but within an effectively non-linear medium (as opposed to the linear character of print).

History.
Nothing I have said here is new. The ideas in this essay are, in practical terms, closely associated with the various forms of “constructionism” that have appeared, mainly in the 20th century, in the education literature. Many names such as Montessori, Dewey, von Glasersfeld, Piaget, Vygotsky and Bruner are associated with different aspects or variations of this.

Having said that, I believe that I have added here a couple of important ideas. The first is to situate the construction (the tasks) in the context of design. In a sense this gives the student a wider set of objectives with more scope for creative ideas and individual input. When I assign the students a particular problem many of them complain that it is too hard. But with a good design project, the problems the students come up against might well be their own. And perhaps they can more readily find their own level.

A second idea, which has been a great revelation to me, is the necessity of redesigning the course structure. In the past I have failed to effectively incorporate design into my curriculum. I now see clearly that success in this requires a significant redesign of the course itself.

Cautions.
- This approach requires time and patience from the student. The student must have (and take!) the time to investigate, to go on side excursions, to “play.” This activity gives new meaning to the term playtime.

- In many ways the students will need to regard themselves in a new way, as the architects of much of their own learning, as being much more in the driver’s seat. They will need help in developing this caste of mind.

- It will be argued that students who go on to further study or graduate work might need most of the traditional content knowledge of the course. However, such students seldom master much of the material in their first year anyway, but consolidate their knowledge later when time and place are right. This new approach ought to help them in that.

- There are significant challenges around student assessment. It’s one thing to design new kinds of tasks and problems, but quite another to design different kinds of tests and exams. This is a major issue that we are just beginning to grapple with. It’s a competitive world and marks mean a huge amount to our students.

Whitehead.
Let me end by crediting one little-known master who was primarily responsible for my original engagement with these ideas and who continued, for the next forty years, to influence me deeply. Alfred North Whitehead is well known as a philosopher and a mathematician, but less well known as an educator. In 1922, while at Cambridge, he wrote an extraordinary essay, The Rhythm of Education which he delivered at a college for teacher training. In this, he identified three stages on which the drama of learning plays out, and he called these Romance, Precision and Generalization.

Romance is the fire, the barely justified leap into the unknown, the creative spark, and Precision is the focused careful taking apart of a complex creature to see the mechanics of its breath. For Whitehead, both of these are essential components of learning, but Romance must take precedence, as it is the source of motivation and energy to feed the patience and dedication that Precision requires. As Whitehead made so clear in his 1922 paper, Romance generates the hunger for Precision and if it is short-changed, as it typically is, the self-discipline that Precision requires is difficult to sustain.

Of course, design is Romance, and construction is Precision.