



The drawing on the left is a bison found on a cave wall in Lascaux, France.
The drawing on the right is a bull by Picasso.
Some 15000 years separate these two paintings.
What exactly has changed?

What the history of art can teach us about teaching.

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In fact a lot has changed. Those years have given us a rich imaginative journey. My purpose is to use that journey to help me solve a problem I've been wrestling with for some years—a problem in curriculum design.

So here's the problem:

I need to cut the amount of material down in my linear algebra course. I want more time and space, light and air—enough to allow me to really engage my students. *Engagement* is a key word here. I want them really focused, committed, always trying to guess my next move, see if they can get there first...

So I need less stuff, that's the key. But when I try to do that, I find it almost impossible to cut back. Taking the old curriculum and trying to prune it down just doesn't work. In its old form it just can't support any significant reduction—for a whole bunch of reasons.

You can guess what some of those reasons are, but just so you know, I'm going to give you the #1 reason, the one bites hardest, at least for me. My course is carefully crafted—everything fits, everything belongs. It's an artistic whole. It seems intolerable to leave any piece out. It is a clear violation of the spirit of the subject. It loses its integrity.

What's to be done? What I think I need is a new curriculum design.

Now before I say any more about that, there's a lot going on here. A new design is only the beginning. Do you think the old content will serve the new design. Don't bet on it.

So we need new content too—new examples, examples of a different kind.

In fact those aren't really two separate things, design and content. It's artificial to try to separate them. They go together; one informs the other; they co-evolve. It's a package.

I was talking to a student the other day about this—changing the system and all that—and he said: *you'll need new teachers too*. Well, yes, that's part of the package too—a different way of teaching. And yes maybe it takes a special teacher to teach in an engaging way. But I think far too much is made of that. The key to special teaching is special material. There are far more excellent teachers working with poor material than there are poor teachers working with excellent material. The limiting resource is the curriculum. Find the right examples; find the right problems, find the right design, and almost every teacher in this university, and I've talked to a number of them, from the dedicated researcher to the webCT whiz, almost everyone of us will be a teaching star. What's more to the point, of course, our students will learn.

More of this later, but for now I want to ponder this new design. What I need, to jump start my imagination here, is a model, or more precisely, a metaphor.

It seems to me that my problem is really the problem of the artist who is faced with a small flat canvas, with an overwhelming story to relate. So I'm going to look at that and see how the response of the artist to the very same problem evolved and grew throughout the centuries. You see, they've been working on this far longer than we have. For at least 150 thousand years in fact.

This talk is a sustained metaphor so that you should be always asking yourself, what is the connection between this and the mathematics curriculum?

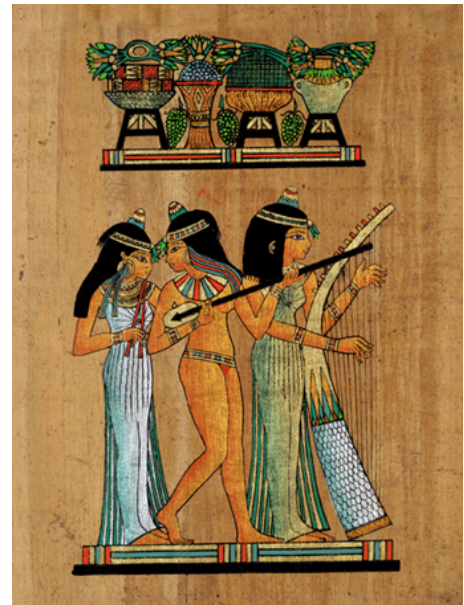
Ancient times.

Art is a representation of the world. You might think that "interpretation" is a better word than "representation," but that's included, a representation always projects the interpretation of the artist. However, for most of the history of painting, representation has meant producing an effect that is as close as possible to observed reality.

In earlier times the problem was stated thus: the world has three dimensions and the canvas has only two. And so the task of the early artist was, using the technical resources at his disposal, to create as much of the three-dimensional effect as possible.

For a long time, progress was slow. Figures were very much 2-dimensional, pasted onto the surface of the painting.

So here's a good question: how do you make life-like figures, with roundness and motion? How do you make the canvas three-dimensional?



The Egyptian musicians papyrus probably somewhat before 1000 B.C.



Maiden gathering flowers and *Diana*. Wall paintings from Stabiae, a favorite Roman resort, which was buried in the eruption of Mt. Vesuvius in A.D. 79. Here we start to see more roundness, more motion.

The high Renaissance.

A lot of wonderful things happened in next 1500 years, and (alas) I'm going to skip them.

Here we have everything, a noble and devout subject, a superbly balanced dynamic composition, stability and movement, the play of light and colour, a striking 3-dimensionality. Here is Rafael on the shoulders of Leonardo and Michelangelo, at the pinnacle of the high Renaissance. Everything at his command—movement, colour, light.

In fact so perfect so definitive was the collection of works of this triumphant epoch that it exerted something like a stranglehold on the industry for the next 300 years—both on a technical and on a conceptual level. Not only how do you do this and how do you achieve that, but what is beauty, what is painting about, and what is worthy of being painted? In all ways, it set the standards of the discipline.

Sound familiar? Here we have the perfect math lecture. The noblest of results. The theorem in its rightful place, served by its faithful lemmas, trailing corollaries of glory, legitimized by the most elegant of proofs.

Now this was a real problem. Imagine if you were a young artist and this was up on the wall. How would you feel?



Raphael Sistine Madonna 1531

How can you be an artist and still uphold such an absolute standard? Artists have to question, to rebel, to push the boundaries.

You can stretch the truth.

Parmigianino
*Madonna of the long neck 1535**

Here grace and elegance have been bestowed on the Holy Virgin through a Barbie doll distortion, though Mattel would not approve of the massive hips, in fact her shape is taken from the vase on the left. At their best, these so called “Mannerist” painters managed to produce striking and original effects and displayed an early striving towards a deviant or idiosyncratic conception of beauty.



Caravaggio
The Calling of Matthew 1600

Here's one that pushes drama and spontaneity—Caravaggio's *Calling of Matthew* in 1600 finds a much richer way to move beyond the Renaissance. Found in a private chapel in Rome, this painting has a naturalism, a fresh capturing of the moment. The gaunt-faced Jesus points dramatically at the tax collector Matthew in a way that recalls God's hand giving life to Adam in the Sistine Chapel. . The dramatic light, the boy at the right who is coming alive in the presence of Christ, the boy at the left who is unaware of the momentous happening, and is thereby condemned. At the right, the young man with his back to us at least realizes something awesome is afoot and reaches uncertainly for his sword. There was a new sincerity here—it is alive with possibilities.



Velasquez
The water carrier of Seville 1619

And here is a painting that pushes into contemporary life—The Spanish painter Velazquez was the greatest painter to emerge from the Caravaggesque school of Seville. *The Water Carrier of Seville* 1619 is a wonderfully naturalistic painting, giving us ordinary people engaged in life's ordinary commerce, but painted with all the intensity and reverence of classical religious themes. It is a superb showcase of the artist's ability to render contrasting textures illuminated by natural light, correction, by dramatic natural light—the glaze of the waterpot at the left, the matte finish of the jug at the right, the clear glass and the waterdrops, the rough wool and dense velvet of the costumes.

Of course, over the past decades we too have taken serious issue with the lofty standard, particularly in the undergraduate classroom. But our variations have been much like those above, essentially bowing down to the mathematical high renaissance.



Nicholas Poussin the Death of Sapphira 1652



Nicholas Poussin the great French academic painter produced grand scenes, superbly balanced, judged, symbolized. He did not really trust nature to be equal to the exacting standards of the masters, but ennobled and embellished his works. . In order to “feel” the composition he built a miniature set populated with tiny wax figures dressed in material and arrange them and rearrange them within the perspective established by converging threads stretched out above the base. He would adjust and direct the lighting at will.

The background in *the Death of Sapphira* is unforgettable. Framed by lines of palaces and steps, the main figures are carefully choreographed and their dominant colours, red, blue and pumpkin, which so often appear in Poussin, are in a balanced design. An immortal moment captured, frozen in time.

Jacques-Louis David
Death of Marat 1793

Another great moment captured. With all the interplay of light and shade. The heroic style.

But the 19th century is about to begin.



The 19th century



Here are two Goyas. Above is *Nude Maja, 1800* at the dawn of the new century. How unlike this nude is from the those of the high Renaissance. The light is overly bright. Mocking the atmosphere. Mocking the heroic style. And her expression mocks us also. Just you wait, it says.

And at the right, *Milkmaid of Bordeaux. 1826.*

I include this as it has been called the first impressionist painting.



*Courbet,
Woman with a Parrot, 1866*

When this painting was shown in the Salon of 1866, critics censured Courbet's "lack of taste" as well as his model's "ungainly" pose and "disheveled hair." Clearly, Courbet's woman was perceived as provocative. The picture, however, was admired by contemporary artists: Cézanne seems to have carried a small photograph of it in his wallet, and in 1866 Manet began his version of the subject, "Young Lady in 1866 (Woman with a Parrot)".



*Corot
Bridge at Nantes 1868*

This has an informality just as the *Water Carrier of Seville*, but it is much less bound by the noble or heroic tradition. I love the way Corot works with light.. Softness, ease, imprecision, informality, gentleness.

Something is starting to happen here There is an entire change of attitude.



*Eugene Delacroix
The Death of Sardanapal 1827*

"The last of the great artists of the Renaissance and the first modern...' Baudelaire's definitive description of Delacroix requires us to explain not only the influences that left their mark upon him, but how he was able to assimilate these; how he made use of them to construct his own originality. This, in its turn, became his own legacy, and his own influence has been very widespread. The lesson that he teaches is clear. It is not enough to imitate the great masters, one must, instead, draw on them for inspiration as one seeks to transcend their achievement..."

From Gilles Neret, "[Eugene Delacroix 1798-1863: The Prince of Romanticism](#)"



Manet's Le Dejeuner sur L'Herbe 1863

When the jury of the official Paris Salon in 1863 turned down 300 works, a storm of protest erupted prompting Napoleon III to order an exhibition of the refused work, the Salon des Refuses, and one of these was, a stylized painting which takes and pointedly updates the age-old theme of the female nude in the landscape. All by itself it provoked a critical avalanche that was a mixture of shock and dismay. Almost everything about it is “wrong”—it appears formless and flat, the perspective is wrong, the woman in the pool looks a lot closer than she can possibly be, the figures look like cardboard cutouts on a painted background. And the juxtaposition of a nude woman and two gentlemen in frock coats, in a casual outdoor setting in a classical pose outrages our sensibilities. Notice how the nude, her face turned not to her companions but directly onto us, involves us in the scene.



This painting has a clear classical pedigree going back to Titian and Raphael, but this was not recognized when it first appeared.



Titian, Pastoral Concert, 1509



Raphael, the Judgement of Paris 1516

Manet
The Balcony 1868

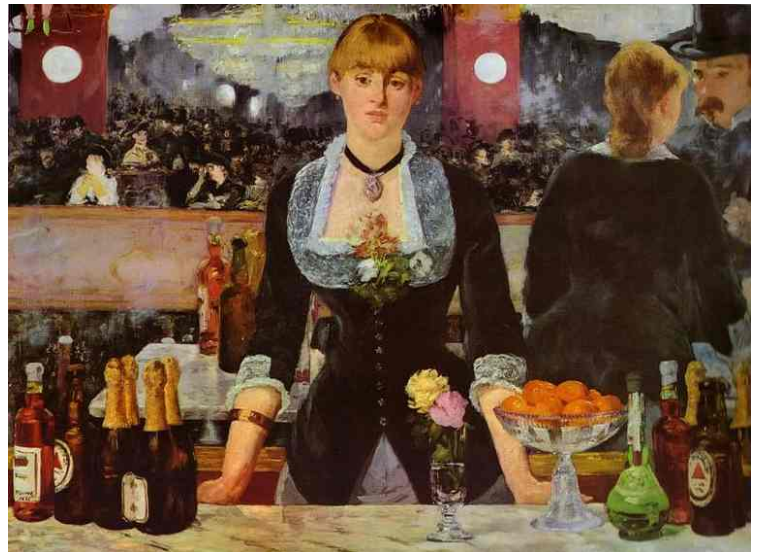
The picture at first seems flat. As if the heads were simply pasted onto the background. To one who was used to the classical style, this painting looked simply inept. Manet used colour to do the work that light and shade had previously done. The impression of depth is achieved by colour rather than by shading, for example the bold green railing which cuts across the picture making the background recede. This painting then has exaggerated colour in the same way that *The Calling of Matthew* has exaggerated light. This interplay between light and shade was a crucial part of early training of any art student and this accounts for the darkness of large portions of the traditional canvas.

But the fact is that in the open air, round forms often do look flat, like patches of colour. *The paradox is that in many important ways this rendering of the scene is closer to the reality that we actually perceive.*



Manet
Bar at the Folies Bergere 1881

His last major painting called by some his most monumental achievement *A Bar at the Folies Bergere* uses the pleasures and gaieties of the Paris life that Impressionism was much taken with as a foil for his own pessimism. The barmaid compares and contrasts with the champagne bottle and her detached melancholy aspect contrasts sharply with the events before her depicted in the mirror. In fact in the same mirror, she appears to lean forward to engage a customer, but in reality she is a million miles away, lost in her own downcast world—the longing for happiness and intimacy amidst the disappointing reality of ordinary existence. It is a picture of sadness, ambiguity, tension.



Monet
Seine at Bennecourt 1868

What is happening here is that we are moving away from the so-called “window” model of classical painting, according to which the surface of the painting was supposed to disappear—as if you were looking through a glass pane onto a scene behind. In a sense, one was almost not supposed to notice that this was a painting at all. However, in using colour to create depth, we are no longer trying to hide the surface, *rather we celebrate it.*

Is that what classical or “ideal” math class was supposed to be?—the teacher presenting the genuine product, almost as if there’s no classroom at all.



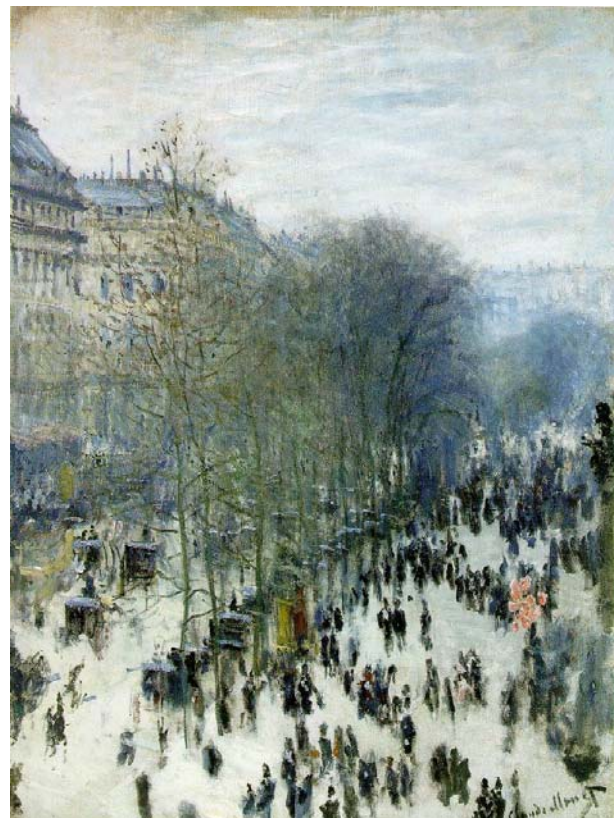
Monet. Blvd des capucines 1873.

Invented in the mid 1800’s, photography emerged and one of its effects was to free painting from the task of recording a person place or happening. In doing so, it left the artist free to be a real artist.

But even more significant—it showed us what a snapshot really looks like. While a photographer can certainly pose his subjects, he can also captured them just as they are, and many were surprised at what they saw. For example, *Bld des Capucines* received all kinds of criticism because the people were just blobs—that’s not what people look like—and that little burst of pink balloons—crude in the extreme. But that’s what you’d see in a photograph! It’s important to pay attention to the difference between what we see and we are told we are supposed to see.

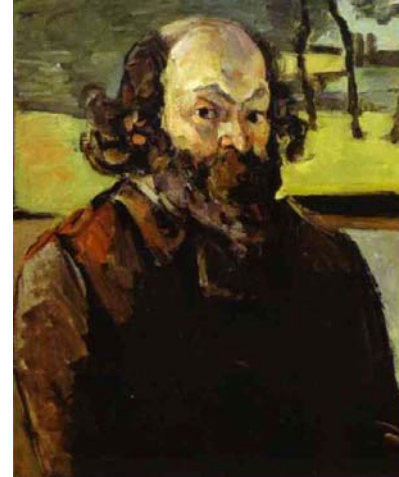
Thus there were two contributions of photography: to capture the moment so that one did not require the services of a painter, and to capture the moment, so that we could actually see what a momentary glance really looks like. Needless to say the air in the 1870’s was full of excited heated exchanges around these ideas and recent discoveries.

It’s the same with technology in the classroom. It frees us and the students from certain tasks; it also let’s us see things we simply didn’t see before.



Cezanne:
Self Portrait 1874

Cezanne wanted his objects to be solid, massive, definitely “there.” Traditional art accomplished that by creating a 3-D effect using a number of technical devices, light, perspective. Cezanne obtained this with colour and form. He built up colours in blocks of paint, using powerful brush strokes. What he did in his pictures was really more a process of hewing than of painting.



Riverbanks
1904-05



Still life with plate of cherries 1886

Quite another and altogether revolutionary way to make the surface 3-dimensional is to offer the viewer multiple points of view. That’s what’s happening here, although a first-time viewer might think the drawing was simply inept. The plates are seen from different angles. The cherries are thrust forward. The plate floats on the table cloth. The table thrusts up in the rear.

Cubism owed a fundamental debt to Cezanne.



Cezanne > Mont St Victoire

Here we see Cezanne's Mont Sainte-Victoire 1904-06 which he painted again and again from different perspectives, trying to capture it, not at a visual but at a structural level—to create an order of art corresponding to the order of nature. The old masters had followed rules of symmetry, order, balance, so that their constructions were necessarily contrived. Cezanne wanted to capture the order that was already in nature.



His works—difficult to figure out, understand, difficult to put your finger on the power which emerges from the geometry of their form and colour. Adjectives used were: coarse, crude, brutal.. Imperceptibly, brutal became the equivalent of powerful and strong. Others: rough clumsy and naïve. Gradually the words naïve and precocious became words of admiration.



Cezanne himself doubted whether his works could be fully understood by those accustomed to the conventional language of representational art, but his declared objective was to make of Impressionism “something more solid and durable like the art of the museums” [1, p 406]

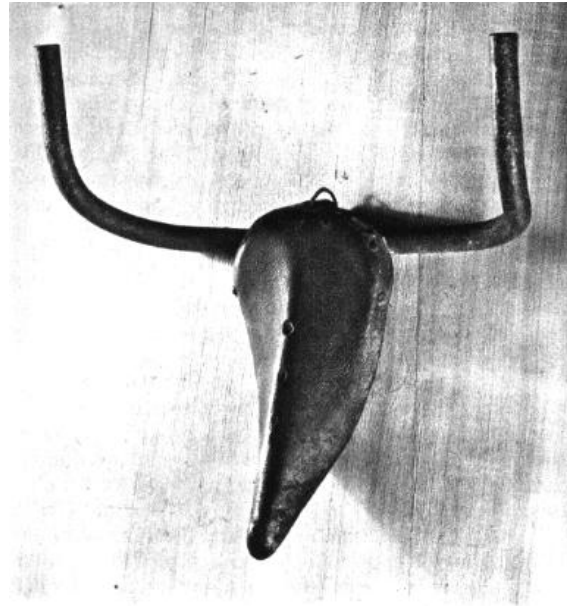
Simple solid structural powerful. Cezanne understood as few had before him, the importance of coming to term with the interaction of mass and space [2: p 155].



The interaction of mass and space. That's a big theme for me and that's probably why Cezanne is at the moment the artist I most read about, most ponder. I'm moving onto Picasso in a moment, but in my own life as a teacher I'm not ready for Picasso yet. I don't quite know how to go there. It's where I hope to get to, but I feel I need to hang out with Cezanne a bit longer first.

Picasso The Bull's Head 1943.

Another Picasso Bull. A very clever bull. The bicycle and the bull—two awesome machines, two wonderful forms of poetry in motion. A simple juxtaposition of two familiar components to make something immediate, alive, totally familiar, totally other worldly, elegant and deep.



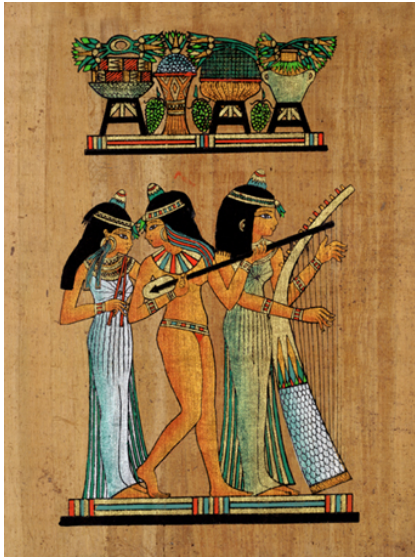
*Picasso
Les Femmes d'Alger (O. J. Version O) 1907*

Of all the movements which grew out of the post-impressionist energy, the one which was to have the greatest influence on modern art was Cubism. And the kernel of Cubism is found in one extraordinary act of perception recorded in the 1907 painting of. Named not after the city in France, but after the red light district on Avignon street in Barcelona. These ladies are from a very new place. They are seven feet tall; they are intimidating and unworldly. It's a frightening picture.

Never before had anything quite like this been seen. In this painting, Picasso had definitively broken free from the two central characteristics of European Art: the classic ideal of human anatomy, and the illusion of space based on the conventional laws of perspective which assumes the viewer observes the scene from a fixed point. Here shapes are distorted, edges are blurred, and the perspective is all over the place, front and back and sideways. The two masks express our dismay, our acute discomfort at a world in which something is badly wrong. The lady above has the first square breast in the history of art, the one below is seen from three angles at once; she represents the dawn of cubism. Even the melon in the foreground warns us away.



Predictably enough, the first reaction to the painting was disapproving, angry, outraged. Matisse called it a hoax with which Picasso was trying to ridicule modern art. For years it lay rolled up on the floor of Picasso's studio. But today it occupies a wall by itself in New York's Museum of Modern Art. It has been said that this painting inaugurated modern art by modifying the nature of the relationship between the painted image and reality and by thus placing the person who looks at it in a position he has never before occupied.



Tentative conclusions.

I am still in the process of knitting all this together. We began with the problem of engagement. Picasso, Cezanne, Matisse, are more engaging for us than the old masters. [But notice the effect of *the Da Vinci code* on one rather famous old master. What's going on there? I suspect it's the puzzle, and the sense of tradition, received wisdom, being overthrown.]

"Art is a lie," said Picasso, "through which one finds the truth.... We all know that art is not the truth--Art is a deception... made in order to approach the truth. The artist has to find a way to convince others of the truth through his deception." I like this quote. It allows me to offer my students something other than the "mathematics of the text books," something more imaginative, and I don't have to worry about its non-traditional nature if they can only find the truth through my deception.

Another Picasso quote. "I paint things as I think of them, not as I see them." [2, p 187]. The student engages primarily with the mind of the teacher, at least *first* with the mind of the teacher and only then with the subject. What they want is to know how we think of things.

How do you start to experience a painting like *LesDemoiselles*? To make that really work you have to be prepared to abandon the tightly ordered hierarchical curriculum. You have to abandon the classical model, the heroic style—because you never know where it will take you, because wherever it goes, you'll have to go with it, both with it and with your students as they clamber to be up there with you. As your mind roves over the different perspectives you have to try to share those different points of view with the students, even when, especially when, they will have trouble with the ambiguity, with reconciling two different stories, two different barmaids in two different worlds who are really the same person. These are the ingredients of engagement.

This takes time and space so you need to struggle to understand the intimate dance between mass and space, content and openness.

And then there's the canvas itself, the limitations of its 2-dimensionality, the classical problem of how to convey empty space. Well we have our limitations and problems too, classes that are too large, students who don't know geometry or trigonometry. But limitations can be turned to strength and a new form of beauty. Don't try to hide the surface, celebrate it. There's more than one way to give depth—use colour and use it boldly.

Go to where the student is. Simple everyday stories have great power for us because they *are* us.

Make full use of the viewer's imagination. Trust the student to fill in the spaces. Now here's where your colleagues will give you problems. What if they get into my third-year course and don't know the intermediate value theorem? It is really hard to trust. But I will say this. If they "let you down," if they never quite get around to filling in the spaces, providing the missing details, then they will probably thrive anyway and more important, the world will be fine. It won't really notice the omission.

So my course isn't a course in linear algebra anymore and therefore I do not have to pay explicit and detailed homage to that subject. Rather the course is centred around a sequence of sophisticated works of art that I have chosen and constructed based on my knowledge of and love of the subject of linear algebra. Those examples are now what defines my course. They form a complete whole each one of them, and so the integrity of my course is restored. Each of these works is explored as fully as appropriate letting the technical chips fall where they may. That is the order that is in nature. The objective is to understand the paintings not in fact the subject. [There is a small but crucial difference here. The understanding of the subject comes later if in fact it comes at all. I recall a small interval in my fourth year when I suddenly understood what linear algebra was all about, though I had taken the course two years before.] And if a teacher further up the road has occasion to ask the student what she knows, she shouldn't answer *linear algebra*; rather she should give a list of the paintings she has studied—and say: *I understand these*. And in many important ways this is a more useful and informative description of where the student stands partly because it provides a sophisticated but concrete benchmark that the new teacher can refer to.

Cezanne, Matisse, Picasso and many others. Rather than provide a definitive depiction of a noble event, they take an everyday event and in their own deeply personal struggle to understand, and to see clearly, they throw it into a new imaginative space— at once elemental, primitive, powerful, arresting, challenging. We are impelled to follow them there, though perplexed, skeptical, maybe even fearful. So we need help, encouragement.

I end in fact with Cezanne, as that's where I think I am right now in my own work. In his intense artistic study of this castle, of that mountain, he seeks to understand what it means to be a castle, what it means to be a mountain. He seeks a new understanding of the natural order of castles which are man and woman made, and mountains which are not and how they stand together.

I believe that we need a new understanding of the natural order of pedagogy which is man and woman made, and mathematics which is not and how they stand together.

Cezanne.
Chateau Noir 1905



[1] Gombrich, E. H. *The Story of Art*, Phaidon press, 1960. Anyone who knows this wonderful book will have realized the huge debt this talk owes to it.

[2] Leonard Shlain, *Art & Physics*, Wm. Morrow and Co. New York 1991.