TACIT KNOWLEDGE IN VITRUVIUS[*]

SERAFINA CUOMO

This paper is an experiment in taking a notion current in the history of modern science and technology – the notion of tacit knowledge - and seeing how it might work when applied to an ancient text like Vitruvius' *De architectura*. Like any preliminary experiment, it is tentative and has no claim to generality, until and unless it be more widely applied and replicated, whether to *De architectura* or to other similar texts from antiquity. In that sense, this paper also attempts to be a manifesto for future studies. It may well be that a full recognition of the 'tacit dimension' of those ancient treatises that are primarily devoted to communicating knowledge of how to make things (aka 'technical' treatises), will substantially change our understanding both of those texts, and of knowledge practices in Greek and Roman antiquity.

I will first briefly describe what historians of science and technology today generally mean by 'tacit knowledge'; then I will look closely at some passages in Vitruvius which, in my view, provide evidence of tacit knowledge. Finally, I will argue that employing the notion of tacit knowledge can not only help us

understand and interpret the text, but also enrich our reconstruction of the context within which that text was read, used, and made sense of by its contemporaries. In other words, applying a notion from the history of science and technology could be of benefit both to the scholarship of *De architectura* as a literary product, and to the readings of it as historical evidence for ancient architecture, Roman 'science', and the Augustan period.

WHAT IS TACIT KNOWLEDGE?

The father founder of the notion of tacit knowledge was Michael Polanyi, who published *The Tacit Dimension* in 1967.[1] In more recent times, however, the name most associated with tacit knowledge, in English-speaking academic circles at least, is Harry Collins, sometimes publishing with other sociologists of science such as Trevor Pinch. Because my aim is not to do a history of the concept of tacit knowledge, but to derive a hopefully useful interpretative category, I will mostly draw on Collins's work and that of his co-authors.

In a nutshell, tacit knowledge consists of the things that we know, and in particular the things that we know how to do, but that are very difficult to express in words. A typical example is riding a bike, or indeed most craft activities

such as carving stone, knitting, blowing glass, or even more quotidian ones, such as cooking. Most of the scholarly literature is about scientific practices, and specifically those, including experiments, which have a strong practical, technical or manual component.

"Tacit knowledge has been shown to have an influence in, among other things, laser-building, the development of nuclear weapons, biological procedures, [...] veterinary surgery",

and how to measure the quality of sapphires. (Collins (2001), 71) The realization that not all knowledge is verbal occurs particularly when knowledge has to be transferred, taught or communicated. Consequently, studies of tacit knowledge focus on training and apprenticing, or in general on learning and acquiring knowledge.

While there is consensus about the general features of tacit or 'personal' knowledge, and various incarnations of it recur in, for instance, the recent scholarship on pedagogy,[2] debate continues on some of the specifics. One of the main points of contention is whether all tacit knowledge can eventually be articulated into words, once it has been identified and made the explicit object of enquiry or discussion, or whether, as Polanyi believed, there will always be an element of tacit knowledge which is ineffable and irreducible in terms of spoken

communication. Historically, it would appear that the same knowledge once

tacitly assumed can emerge and be articulated at a later stage, especially in a

situation of conflict, dispute, or when there is a problem of replication. Whether

that is the case for *all* the knowledge content implied in a scientific or technical

practice, remains contested.

Without taking sides on this particular point, what I think is a useful insight for

our present purposes, is the idea that, if most knowledge-how is tacit, and *a*

fortiori if some knowledge-how will always be tacit, the only effective way of

transmitting it is through direct, personal contact and observation. To quote

again from the scholarship on modern science:

"The traditional or 'algorithmical model' treats the transmission of skills as a

matter of the transfer of bits of information, such as could be expressed in

written form or even in computer programs. Within such a model, all elements of

a given skill can be exactly specified. Written instructions, recipes, and detailed

manuals are, in principle, all that are necessary for the learning of a new skill."

(Pinch, Collins, Carbone (1997), 101)

Correspondingly, 'algorithmical' interpretations of Vitruvius' *De architectura* have

approached the text as a 'manual' of instruction, only to discover, with

disappointment, that you cannot really use it on its own in order to learn how to

build things.[3] The expectation that you could use ancient works about machines as instruction manuals, as you would with a booklet for Lego©, misses the point entirely, and not simply because Vitruvius' *De architectura* is a literary construction, with at best a tenuous connection with real life and real buildings. If the scholarship on tacit knowledge is correct, it may be simply - objectively, cognitively - impossible, even today, let alone in the first century CE, to produce a text that will give you 'perfect' algorithmic instructions to build anything.[4] To quote from the same article again,

"The newer 'enculturational model' […] holds that most of the time the transmission of skills is best seen as a process of socialization – like attaining fluency in a language. Within this model, written instructions alone will never suffice in the learning of a skill. Skills must be learned in situ and certain tacit elements of a skill can only be passed on by direct instruction from a skilled practitioner." (Pinch, Collins, Carbone (1997), 101)

Pinch, Collins and Carbone give us a useful distinction between the kind of communication that can be entirely confined to the written page, and the kind of communication of which the written page is only a part. When looking at so-called 'technical treatises', we should be careful not to think that the transmission of the 'technical' content could ever be entirely resolved within the space of a

written text. More recently, Collins has introduced the idea of collective tacit knowledge. He argues that, even after you have mastered a skill, for instance, driving a car, you still have to master that skill within the context of use and especially the context of other people using that same skill, i.e. different tacit rules of traffic such as we find around the world. (Collins (2010), chapter 6) That puts even more constraints on our capacity, or the possibility *tout court*, to learn how to do things that are social things (and buildings definitely are social things) entirely from a book.

So much for definitions – let us see if we can locate tacit knowledge in Vitruvius' text. This is doubly experimental, in that the work done in the sociology of knowledge is based on the evidence of practices – on direct and sometimes participant observation of scientists' behaviour and interviews with living people – rather than texts whose contexts can be reconstructed only conjecturally. Nevertheless, recognizing the presence of tacit knowledge as a limit not just of Vitruvius' text, but of any text which aims to transmit knowledge, will help us gain insight into something that is highly problematic for Vitruvius himself, namely, how to express a knowledge practice through a text, or how to write about architecture at all.[5]

LOCATING TACIT KNOWLEDGE IN VITRUVIUS

Once you start looking, it is striking how pervasive tacit knowledge appears to be. Almost every gap could now potentially be a presence – as could every passage where Vitruvius, while explaining some things, takes other things entirely for granted. This happens most obviously in those parts of the text where he describes machines, such as book 10.[6] There, in the final book of the treatise, the reader is given instructions about how to put pieces together and in what sequence:

"Two wooden beams proportional to the size of the load are procured. They are erected and fastened together at the top with a bolt and spread apart at the bottom; they are held upright by ropes tied to them at the top and fixed in the ground at intervals around them. A pulley-block, which some also call a rechamus, is fastened at the top. Two pulleys revolving on axles are inserted into the pulley-block: a traction-rope is passed around the upper pulley, then is let down and taken round the pulley in the lower pulley-block; then it is brought up again to the lowest pulley in the pulley-block at the top, and once again goes back down to the lower pulley-block, where it is tied off in a hole. The other end of the rope is brought back down between the feet of the machine. The socket-

pieces in which the ends of the windlasses are fixed so that the axles may turn freely are secured to the flat, rear surfaces of the beams at the point where they spread apart. Near the ends of these windlasses are two holes arranged so that hand-spikes can be fitted into them. Iron pincers, of which the points fit into the holes drilled in stones, are fastened at the bottom of the lower rechamus. When one end of the rope is fastened to the windlass and the latter is turned using the hand-spikes, the rope winds itself round the windlass and becomes taut, and so raises the loads to the height and location of the work being undertaken. This type of machinery, which depends on the rotations of three pulleys, is called a trispastos."[7]

Notice how Vitruvius 'baptizes' the machine itself, and 'translates' one name (*trochlea*) into another (*rechamus*), even though he proceeds to use both. (Cf. Fleury (2005) 282) Assigning a name to a thing eliminates the need for more ostensive communication, be it in the form of a longer description, or of visual aids. Notice also, on the other hand, the things that are left unsaid: we are told that a *trochlea* is what some call a *rechamus*, but not what the object is, nor what exactly *fibula, axiculus, orbiculus,* or *chelonia* are.[8] Many terms for components of the machine are used as if the reader already knew what the corresponding things would look like and function as, and perhaps even how they would have

been made in their turn. The whole of the trispastos may be treated as new knowledge, but it is assembled from pieces that are taken as given. Moreover, knowledge of the processes by which the given pieces are assembled, is also in part taken as given. Some imply complex manual skills, such as fastening and fixing ropes or securing pieces in position; some present as more mathematically demanding, such as, at the very beginning of the passage, the stipulation that the two beams have to be in proportion to the weight that needs to be lifted. If not mathematics, here Vitruvius is at least assuming experienced eye-balling, otherwise the machine may just collapse under an excessive load.

Let us look at another passage, here the description of how to build what we would call an Archimedean screw:

"This device is constructed as follows: a wooden beam is selected and its length in feet should be measured out so as to equal its diameter in inches. It should then be made circular in section using compasses. The circumferences at the ends [of the beam] should be divided with compasses into eight segments comprising quadrants and octants; the lines should be located so that when the beam is laid down horizontally, those at either end line up exactly with each other; and the spacings marked along the length of the beam should equal an eighth of the circumference at the ends. Again, when the beam has been laid flat,

perfectly straight lines should be drawn from one end of it to the other. In this way equal spaces between the lines will be generated both around the circumference and along the length of the beam. So where the lines have been drawn along the length of the beam they will create intersections [with the circumferential lines], and precise points at the intersections. When these lines have been drawn correctly, one takes a thin strip of willow or one cut from agnus castus which, after being smeared with liquid pitch, is fixed at the first point of intersection. Then it is taken diagonally across to the next points of intersection of the longitudinal and circumferential lines; then, progressing in due order, it goes through each point and, winding around the beam, should be attached to each intersection; in this way, moving back from the first to the eighth point of intersection, it arrives at and is secured to the same line to which its end was fastened at the beginning. [...] More and more strips of wood coated with liquid pitch are fixed one over the other along the same grid, and should be built up until the total thickness is an eighth of the length. Wooden boards are placed above and around these strips and secured so as to protect the spiral. Then these boards are soaked with pitch and bound together with iron strips so that the impact of the water will not force them apart. The ends of the beam are shod with iron. To right and left of the screw, vertical supports are put in position at

either end, with cross-beams fixed on both sides. In these cross-beams iron

sockets are inserted in which the pivots are housed; and so the screws turn,

powered by the men pushing with their feet. The screw will be set up with an

inclination that should correspond to the way in which a Pythagorean right-

angled triangle is drawn; that is, its length should be divided into five units, of

which three indicate the height of the upper end of the screw, so that the

distance from the perpendicular to the apertures at the bottom will be four units.

A diagram is drawn at the appropriate place at the end of the book showing the

procedure which should be followed."[9]

The range of knowledge implicit in the building of this water-lifting device, which

we know to have actually existed in antiquity,[10] is even wider than what we found

between the lines of the description of the *trispastos*, to the point where it

evokes, beyond the individual presumably supervising the work, a team of people

contributing to different aspects of the machine. The design of the screw is

exquisitely mathematical, in the concrete, instrument-based Vitruvian sense of the

term that we will discuss below. While for some aspects 'simple', the geometrical

construction outlined here implies that the person doing it is an expert user of

the compasses and presumably of a carpenter's square or similar instrument, so

that they will know how to divide a circumference into equal parts and how to

produce perfectly straight lines, both procedures that are taken for granted in the text. Moreover, we find the same tacit assumptions here as we did in the earlier passage, regarding manual skills such as fixing, attaching, and coating with pitch. Reading these absences of information helps us put together what Vitruvius expected, if not his reader, then at least a fellow builder, to know. In fact, one wonders whether the famous all-encompassing depiction of the ideal architect in book 1 is not at least to some extent a map of an expert builder's expected background/tacit knowledge. In book 1, the mathematical requirements of a good architect are all about how to use ruler and compasses, and geometrical constructions (as opposed to, say, demonstrations in the Euclidean mould) produced by means of instruments are found elsewhere in the treatise.[11] Mathematical constructions of physical artefacts with even more of a geometrical internal structure than the Archimedean screw are a particularly interesting further example of how tacit knowledge can be located in *De architectura*. Take the rose of the winds in book 1 (1.6.6-8, 12-13), or the analemma in book 9 (9.1.1):

"in any places where dials will have to be traced out, in that place the equinoctial shadow has to be taken, and if the nine parts of the gnomon will be as in Rome, an octet of shadow, let a line be traced on a level surface and from its middle let

[a line] be erected perpendicularly so that it is at a right angle, which is called gnomon, and from the line which will be flat on the line of the gnomon let nine spaces be divided with the compass, and in the place where is the mark of the ninth part let the centre be established where the letter A will be, and having opened the compass from that centre to the line of the flat surface where the letter B will be, let a circular line be drawn, which is called meridian. Next, of the nine parts between the flat surface and the centre of the gnomon, let 8 be taken and be marked on the line which is on the flat surface, where the letter C will be. This then will be the equinoctial shadow of the gnomon. And from that mark and the letter C through the centre where is the letter A let a line be drawn, where the equinoctial ray of the sun will be. At the same time, having opened the compass from the centre to the line of the flat surface let an area of equidistant width be marked where the letter E will be on the left side and I on the right [side] at the endpoints of the circular line, and through the centre a line has to be drawn, so that two semircircles be divided equally. This line then is called by mathematicians the horizon. [...] From the equinoctial centre with a distance [equivalent to the] summer [ray], let the circular line of the monthly circle be drawn, which is called monthly line (menaeus). Thus the design of an analemma will be obtained."[12]

It would be very difficult to build an analemma solely on the basis of Vitruvius' description, unless one already knew what the geometrical construction looked like (in other words, unless one already had a diagram), unless one had already seen a sundial, unless one already knew how to project the geometrical construction onto the plane of the chosen object which is to become a sundial, and, as in the previous cases, unless one already was an expert user of ruler and compasses. Once again, the absences in the text are explained by the ineffable, or at least unspoken, ability on the one hand to create a network of geometrical lines by means of instruments, and on the other, to embody that geometrical construction into a material in such a way as to produce an accurate yet serviceable artefact.

The case of the analemma also throws into sharper relief the issue of the role of diagrams, and the emphasis they ought to be given in an interpretation which takes tacit knowledge on board. Ancient diagrams come in many guises: the lettered diagram of axiomatico-deductive geometry is an integral part of the proof, and of its shift from general to particular, to general again.[13] The numbered diagram of problems aimed at measurement, such as we find in many papyri, is both an illustration and an aid to the understanding and memorization of the procedure.[14] The diagram of a geometrical construction aimed at

constituting the substratum of an artefact is an explicitation, through visualization, of what the text can only gesture towards – it is basically encapsulated, but visually articulated, tacit knowledge.

Diagrams in Vitruvius tend to intervene when the text is pushed to its limits,[15] so that they appear in the treatise only occasionally,[16] as if at that moment Vitruvius' awareness of the need to show, and not just tell, had been particularly amplified. When Vitruvius talks about the contrast between doing and talking in book 1,[17] according to Pierre Gros what he really wants to say is that words can be more effective than things. Consequently, Gros claims that diagrams would be an admission of the impotence of words over things, and that is why they are so sparingly used in *De architectura*.[18] While I agree that diagrams are, as I said above, a 'special measure'-type of intervention onto the text, I am not sure that the need to show is necessarily perceived by Vitruvius as a failure, as opposed to, more neutrally, par for the course, especially when communicating to an audience which includes non-builders.[19] Indeed, the very same passage in the first book about *fabrica*[20] and *ratiocinatio* and *quod significatur* and *quod significat*, steers a very even course between the two pairs of terms, before culminating, after the description of the ideal architect and before starting to

subdivide architecture, in a passage where, in my view, Vitruvius lands

unequivocally on one side of the fence:

"For it is not as a consummate philosopher, nor as a fluent rhetorician, nor as a

grammarian practised in the highest skills of his art that I have laboured to write

these books, but as an architect who only dipped his foot in these studies. But

with respect to the power of the art and the reasonings that are part of it, I

promise, and hope, that by means of these books I will provide an unequivocally

authoritative account not only for those who build but also for all men of

culture."[21]

I think that the extent to which this passage may manifest an 'inferiority complex'

has been overstated. [22] If we found something similar in Cicero or Varro, we

would probably see it as straightforward *captatio benevolentiae* by way of

exaggerated modesty, and I think that is a much more plausible reading. The

contrast Vitruvius sets is not just with any philosopher, but with a *summus*

philosophus, not just with any rhetorician, but with a *rhetor disertus*, and so on –

qualified modesty, in other words. For his part, the terms framing what Vitruvius

is doing with his architectural treatise are all very strong: *potestas*, *maxima*

auctoritas and *sine dubio*.

On the whole, Vitruvius is well aware both of the power, and of the limitations of written-down, codified knowledge. Sometimes this realization is articulated quite explicitly. For instance, after describing the hydraulic organ, again in book 10, he says:

"I have done my utmost to set out an arcane subject clearly in writing, but its mechanism is not simple or immediately understood by everybody apart from those who already have practical experience of these kinds of instruments. But if anyone has understood little from my account, he will certainly find that I really have laid out everything carefully and precisely when he becomes familiar with the device itself."[23]

Notice that in the *captatio benevolentiae* above, the limits of writing are cast in terms of Vitruvius' own area of expertise, which turns into an opportunity for highlighting by contrast, the areas in which he does have *auctoritas*. In the passage about the water-organ, on the contrary, the limits are presented as more or less 'objective' or neutral with regard to Vitruvius' own literary skills – in other words, this is not a matter of not finding the right words, but of there being no right words, or no words that can really substitute *exercitatio* and familiarity with the actual artefact itself.

At other times, the discrepancy between words and the world emerges in a more subtle way. The design of temples in books 3 and 4, as well as the planning of theatres in book 5 (5.6 *passim*, 5.7.1), all presuppose the expert use of ruler and compasses (3.3 *passim*, 3.5 *passim*, 4.3 *passim*, 4.6 *passim*), which is assumed as background but not brought to the fore for discussion. Nonetheless, even when knowledge can be articulated and codified in sets of mathematical proportions, as it often is in these books, Vitruvius makes it very clear that geometrical constructions must adapt to the circumstances. Thus, tacit knowledge slips in through the ever-present factors of uncertainty or inaccuracy, such as the nature of the site, the scale of the work, in its turn a function of money and time; and in the case of temples, what god one is building for. A good architect should know how to adapt, which in mathematical terms amounts to knowing how to tweak and what to tweak,[24] but this is precisely the sort of knowledge that cannot be written down in a treatise:

"Nothing should preoccupy the architect more than that buildings should incorporate exactly the measurements implicit in the proportional system based on a predetermined unit. Therefore, when the system of modular relationships has been established and the relative dimensions worked out by calculation, it requires an acute mind to consider the nature of the site, its use and appearance,

and to make adjustments by means of additions or subtractions when something

in the modular system must be augmented or reduced so that it can be seen to

be designed correctly without damaging its appearance. [...] Therefore, since what

is real may seem false and some things may turn out to be different from how

they appear to the eyes, I do not think that there is any room to doubt that

subtractions or additions should be made to cater for the characteristics and

exigencies of sites, but in such a way that the buildings leave nothing to be

desired. But such results cannot be achieved by precepts alone but also require

fine judgement (*acumen*)."[25]

Acumen belongs to a family of crucial but underdefined notions such as

venustas,[26] which may be immediately identifiable by the members of a certain

knowledge community, but are very difficult to explain to an outsider. A modern

equivalent could be the notion of 'elegance' in a mathematical proof. A trained

mathematician will recognize it, but they will not be able to explain it to you

unless you are one of them, at which point you will not need the explanation

anymore because you just know. Although *venustas* has to do with *symmetria*

and thus can to an extent be expressed in mathematical terms, it cannot entirely

be reduced to mathematical proportions, because those proportions will have to

be adapted to the circumstances, as explained above. It could be argued that

some crucial but somewhat under-determined Vitruvian epistemic virtues such as

ingenium, *acumen*, *sollertia* are a sort of short-hand for more extensive but tacit,

indefinable, moral and cognitive behaviours and approaches which are learned or

almost 'absorbed' non-verbally when someone (an architect) is enculturated

within a knowledge community (the community of expert builders). These terms

appear to be often used by Vitruvius to fill the explanatory gap opened by the

limits of the text in accounting for how things get built successfully.[27]

CONCLUSION

Identifying the presence of tacit knowledge in Vitruvius' treatise, in the way that I

have sketched in this article, may help us in various ways better to understand

the text and its author.

Firstly, assuming tacit knowledge rather than incompetence or poor literary skills

may help explain 'gaps' in the account, including explaining why the machines

described often 'do not work'.[28]

Secondly, inserting tacit knowledge into the picture may throw further light on

the problem of transmission of technology, and on the limits of the text in that

transmission.[29] It seems to me that there is perhaps an excessive tendency in the

scholarship to attribute transmission of the knowledge found in *De architectura* or technical knowledge in general, to textual sources. (See e.g. Novara (2005), chapter 1; Courrént (2011), 43-50) For instance, this tendency underlies, in my view, the postulated existence of 'subliterary handbooks'. (Oleson (2004) 66) I find the very term 'subliterary' problematic - any text is, in its own way, 'literary', unless we envisage a highly visual text, akin to the Artemidorus papyrus or indeed a Lego© booklet, but, arguably, even that would not have been sufficient to transmit knowledge all by itself, any more than, say, Leonardo da Vinci's codexes enable us to reconstruct his machines without having to fill any gaps. Moreover, I am skeptical about postulating the existence of texts for which we have no evidence and which, in a sense, do not need to exist, once we take on board the fact that knowledge, especially technical knowledge, is transmitted mostly extra-textually. Indeed, Burkhard Meißner points out that the idea of writing down the content of crafts only originated in the 19th century. Until then, one educated imitatively, through *Mitmachen-Lassen*, oral discourse and personal demonstration,[30] a picture which, incidentally, fits perfectly with the findings of scholars studying transmission of technology and the role of tacit knowledge even today.

Thus, assuming tacit knowledge emphasizes the importance of people as sources of information, even outside the context of what we would recognize as formal training, and highlights the importance of those passages in *De architectura*[31] and indeed other texts which imply that the actual presence of an expert is paramount. (E.g. Apollodorus, *Siege-matters* 137-138 (ed. Wescher, tr. D. Whitehead)

Thirdly, presupposing tacit knowledge helps us clarify what role Vitruvius envisaged for himself. I think anybody would agree that *De architectura* is not just about architecture, but also about the architect, and more specifically about Vitruvius. When in book 1 he distinguishes between doing something and thinking or indeed talking about what you have done, and he says that the first thing is what most craftsmen do, while the second thing is what one shares with the educated, I doubt he is declaring he wants to only do the latter.[32] Vitruvius never forgets where he is coming from. As I understand it, *De architectura* is ideally to be read along with the direct communication and guidance of an architect - in the case of the Emperor, Vitruvius himself. He does not eliminate the role of the architect as a personal, real-life teacher and guide - and why would he? - rather, the personal role of the architect is retained alongside the creation of a text. The text gives the architect *auctoritas*[33] but does not substitute

him, and indeed, if tacit knowledge is a nigh-universal observable cognitive

phenomenon, even the most perfect text could not entirely substitute the expert.

I would re-read the end of book 10 in precisely this light: not even the best

military engines can completely substitute the 'human factor' embodied by the

architect and his *sollertia*. (10.16.1-2, 12)

Assuming tacit knowledge in *De architectura* also makes it clear that, for all the

emphasis on Vitruvius as the author, this is also about a group - a move which

takes us outside the text. The notion of tacit knowledge is inseparable from that

of a knowledge community within which a person is enculturated (to use Pinch's

words). Hence Vitruvius' great interest in defining the architect against other

categories, and distinguishing the good architect from the bad one. *De

architectura* presupposes a group or community of builders: in the preface to

book 1, when he talks about his own service under Julius Caesar, it is significant, I

think, that Vitruvius lists all his colleagues, and specifies that they did things

together.[34] At the same time, I would not want to argue that the community of

architects is completely separate from the non-architects. On the contrary, it is

precisely because architects and *docti*, or even architects and the general public,

share something, that it makes sense for a treatise like *De architectura* to be

written. As already pointed out by Elisa Romano and Pierre Gros, the preface to

book 1 insists on the fact that Augustus has a great interest in building, and already builds on a large scale. At the end of the preface Vitruvius says that he wrote the treatise so that Augustus could have knowledge of buildings to be erected in the future, and of buildings already done.(Vitruvius 1.preface.3. Cf. e.g. Romano (1987), chapter 1; Gros (1994); McEwen (2003) chapters 2 and 4) Augustus is not the only 'lay builder' looming large in the treatise: the *patres familiarum* also have something in common with the architect, but need to be guided and educated in their choices.[35]

In sum, while Vitruvius was certainly not aware of tacit knowledge as such, since the concept was not articulated until the 20th century, he was aware of the limits of the text. Acknowledging tacit knowledge means that we acknowledge that the limits of the text are not necessarily Vitruvius' limits, but that there are what we could call objective limits. Ways Vitruvius has of addressing them include diagrams or recourse to personal virtues such as *ingenium*, *sollertia*, *acumen*, or general values, such as *decor* or *venustas*, which even when defined are to a great extent implicitly understood.[36]

In my view, Vitruvius did not perceive the limits of the text in a completely negative way, because the explanatory gap left by the text could then be filled by the live presence of the expert. Mapping tacit knowledge can give us an idea of

what an enculturated architect was expected to know - ruler and compasses

constructions, for instance - but also, fundamentally, that the architect was

expected to adapt his knowledge to the circumstances, and this was something

that no book could tell you, a limit of the text that, for all his literary resonances

and educated allusions, Vitruvius seems not to see as a failure, but as an

opportunity.

Acknowledging collective tacit knowledge means that we recognize that writing

down the knowledge of building in a *corpus* confers *auctoritas* on the architects

and makes them share, with limitations, in the culture of the *docti*, but also that it

exposes the fact that the *docti* cannot entirely share in the culture of the

architects either. (Cf. Gros (1994), 75-90) it reminds us, historians and philologists,

professionals of the word, that writing or even speaking are not everything, and

that they are not necessarily or not always prior to other forms of

communication.

To quote from modern scholarship again:

"Over the last three decades, an alternative account of scientific knowledge has

gradually emerged to rival the traditional view. In the latter, scientific knowledge

and science-based technology are universal, independent of context, impersonal,

public, and cumulative; the practice of science is (or ought to be) a matter of

following the rules of scientific method. The alternative account emphasizes

instead the local, situated, person-specific, private, and noncumulative aspects of

scientific knowledge. [...] Explicit knowledge is information or instructions that can

be formulated in words or symbols and, therefore, can be stored, copied, and

transferred by impersonal means, such as in written documents or computer files.

Tacit knowledge, on the other hand, is knowledge that has not been (and

perhaps cannot be) formulated explicitly and, therefore, cannot effectively be

stored or transferred entirely by impersonal means. [...] Because tacit knowledge

is transmitted person to person, there are greater barriers to the spread of

competence than the traditional view might lead us to expect. If science rests

upon specific, hard-to-acquire, tacit skills, then there is a sense in which scientific

knowledge is always local knowledge." (MacKenzie & Spinardi (1995), 44-6)

Ultimately, we may be in need of revising our entire notion of knowledge, tacit or

otherwise, so as not to impose on Vitruvius and on *De architectura* a vision of

science that not only did not exist in antiquity, but has probably never existed

anywhere.

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* Unless otherwise indicated, all quotations from *De architectura* are from the

Belles Lettres editions, and all the English translations are a slightly modified

version of the Penguin translation.

[1] Some ideas were already adumbrated in his *Personal Knowledge* (1958). Polanyi was a physical chemist.

[2] E.g. Scribner & Cole (1973). More recently, Tehrani & Riede (2008).

[3] E.g. see the references in Tosi (1994).

[4] Unless, of course, you are building Lego©, and even then one could argue that some information comes from the context or from a helping parent who has been there before, rather than the text.

[5] Cf. e.g. Vitruvius, 4.preface.1: "Cum animadvertissem, Imperator, plures de architectura praecepta voluminaque commentariorum non ordinata sed incepta uti particulas errabundas reliquisse, dignam et utilissimam rem putavi tantae disciplinae corpus ad perfectam ordinationem perducere et praescriptas in singulis voluminibus singulorum generum qualitates explicare." On this see e.g. Pierre Gros's commentary *ad locum* in his edition of book IV (Les belles lettres 1992); McEwen (2003) chapter 1.

[6] The entire section on *ballistae* is a prime example of tacit knowledge implicit in the assemblage of the various parts, whose general shape must be already familiar, as must be choice of material – the only thing that Vitruvius is awovedly talking about is relative proportions (10.11 *passim*). For a valuable discussion of the same problem, but in different terms see Fleury (2005).

[7] Vitruvius, 10.2.1-3 (ed. Fleury with modifications): "Tigna duo ad onerum magnitudinem ratione expendiuntur. A capite [a] fibula coniuncta et in imo divaricata eriguntur, funibus in capitibus conlocatis et circa dispositis erecta retinentur. Alligatur in summo troclea, quem etiam nonnulli rechamum dicunt. In trocleam induntur orbiculi per axiculos versationes habentes. Per orbiculum traicitur ductarius funis, deinde demittitur et traducitur circa orbiculum trocleae inferioris. Refertur autem ad orbiculum imum trocleae superioris et ita descendit ad inferiorem et in foramine eius religatur. Altera pars funis refertur inter imas machinae partes. In quadris autem tignorum posterioribus, quo loci sunt divaricata, figuntur chelonia in quae coiciuntur sucularum capita, ut faciliter axes versentur. Eae suculae proxime capita habent foramina bina ita temperata ut vectes in ea convenire possint. Ad rechamum autem imum ferrei forfices religantur, quorum dentes in saxa forata accommodantur. Cum autem funis habet caput ad suculam religatum et vectes ducentes eam versant, funis involvendo circum suculam extenditur et ita sublevat onera ad altitudinem et operum conlocationes. Haec autem ratio machinationis, quod per tres orbiculos circumvoluitur, trispastos appellatur."

[8] See the remarks on *fibula* in Philippe Fleury's commentary *ad locum* in the Belles Lettres edition of book X (1986) : "une identification précise de la *fibula*

peut être parfois difficile"; Corso & Romano's commentary *ad locum* to their Italian translation (Torino 1997): "V. distingue I componenti di una carrucola [...], ma non dice niente sul materiale di cui sono composti [...] né della disposizione delle pulegge quando ce n'è piú d'una."

[9] Vitruvius, 10.6.1-4: "Eius autem ratio sic expeditur. Tignum sumitur, cuius tigni quanta paratur pedum longitudo tanta digitorum expeditur crassitudo. Id ad circinum rotundatur. In capitibus circino dividentur circumitiones eorum tetrantibus et octantibus in partes octo, eaeque lineae ita conlocentur ut, plano posito tigno, utriusque capitis ad libellam lineae inter se respondeant, et quam magna pars sit octava circinationis tigni, tam magna spatia decidantur in longitudinem. Item, tigno plano conlocato, lineae ab capite ad alterum caput perducantur ad libellam convenientes. [...] Eo modo quantum progreditur oblique spatium et per octo puncta, tantundem et longitudine procedit ad octavum punctum. Eadem ratione per omne spatium longitudinis et rotunditatis singulis decusationibus oblique fixae regulae per octo crassitudinis divisiones involutos faciunt canales et iustam cocleae naturalemque imitationem. Ita per id vestigium aliae super alias figuntur unctae pice liquida, et exaggerantur ad id uti longitudinis octava pars fiat summa crassitudo. Supra eas circumdantur et figuntur tabulae quae pertegant eam involutionem. Tunc eae tabulae pice

saturantur et lamminis ferreis conligantur, ut ab aquae vi ne dissolvantur. Capita tigni ferrea. Dextra autem ac sinistra cocleam tigna conlocantur in capitibus utraque parte habentia transversaria confixa. In his foramina ferrea sunt inclusa inque ea inducuntur styli; et ita cocleae hominibus calcantibus faciunt versationes. Erectio autem eius ad inclinationem sic erit conlocanda uti, quemadmodum Pythagoricum trigonum orthogonium describitur, sic id habeat responsum, id est uti dividatur longitudo in partes V, earum trium extollatur caput cocleae; ita erit ab perpendiculo ad imas naris spatium earum partium IIII. Qua ratione autem oporteat id esse, in extremo libro eius forma descripta est in ipso tempore."

10 See e.g. Andrew Wilson's entries in Oleson (2009).

11 Vitruvius 1.1.4, cf. 1.2.2. Book 9 preface.4-5 starts with Plato's geometrical construction of a square double a given one; having said twice that the double square cannot be found through numbers, Vitruvius gives the construction *grammicis rationibus*. Vitruvius 9.preface.6 is about Pythagoras' geometrical instrument (*norma*): "Item Pythagoras normam sine artificis fabricationibus inventam ostendit, et quod magno labore fabri normam facientes vix ad verum perducere possunt, id rationibus et methodis emendatum ex eius praeceptis explicatur." Vitruvius 9.preface.13: mentions of Archytas and Eratosthenes on the duplication of the cube, thus again a geometrical problem and a geometrical

instrument (the mesolabe). Diagrams (*formae*) at the bottom of the page are mentioned at 9.preface.5 and 9.preface.8.

[12] Vitruvius, 9.7.1-7 (ed. Fleury with modifications, tr. mine): "in quibuscumque locis horologia erunt describenda, eo loci sumenda est aequinoctialis umbra, et si erunt quemadmodum Romae gnomonis partes novem, umbrae octonae, describatur linea in planitia et e media *pros orthas* erigatur ut sit ad normam quae dicitur gnomon, et a linea quae erit planitia in linea gnomonis circino novem spatia dimetiantur, et quo loco nonae partis signum fuerit centrum constituatur ubi erit littera A, et diducto circino ab eo centro ad lineam planitiae ubi erit littera B, circinatio circuli describatur, quae dicitur meridiana. Deinde ex novem partibus, quae sunt a planitia ad gnomonis centrum, VIII sumantur et signentur in linea quae est in planitia ubi erit littera C. Haec autem erit gnomonis aequinoctialis umbra. Et ab eo signo et littera C per centrum ubi est littera A linea perducatur, ubi erit solis aequinoctialis radius. Tunc a centro diducto circino ad lineam planitiae aequilatatio signetur ubi erit littera E sinisteriore parte et I dexteriore in extremis lineae circinationis, et per centrum perducenda linea, ut aequa duo hemicyclia sint divisa. Haec autem linea a mathematicis dicitur horizon. [...] E centro aequinoctiali intervallo aestivo circinatio circuli menstrui agatur, qui menaeus dicitur. Ita habebitur analemmatos deformatio."

[13] See Nezt (1999).

[14] See [*omissis*].

[15] Which I think is in line with Gros (1996), even though he does not use the term 'tacit knowledge'. Gros remarks (1996), 26, that there are only nine diagrams in the whole treatise – this echoed by Haselberger (1989), 69-70.

[16] Cf. in addition to the references in footnote 17, Vitruvius 3.3.13; 3.4.5; 3.5.8; 5.4.1, 5.5.6; 8.5.3; 10.6.4.

[17] Vitruvius 1.1.1-3. See e.g. Gros (1982) 670-1; Romano (1987), 52-9; Callebat (1994), 35-6.

[18] Gros (1996) n21, 25-7: "En général Vitruve ne recourt à un complément graphique que s'il éprouve quelque difficulté à exprimer clairement la démarche à suivre pour construire un élément de structure ou de décor. [...] Il apparâit ainsi que la figure ne prend le relais du texte que dans les cas très ponctuels où Vitruve a conscience d'avoir atteint les limites de sa formulation et/ou de sa conceptualisation. [...] En ce sens le passage du graphisme à l'écriture constitue pour Vitruve l'un des moyens – le principal sans doute – d'élever la praxis architecturale au niveau d'une *ars liberalis* [...]. Dans cette perspective tout retour au dessin est, à certains égards, un aveu d'impuissance et va directement à l'encontre de l'ambition de l'auteur du traité.").

[19] Gros (1996) 27: "Transcrit dans la conception vitruvienne, ce principe revient à affirmer que la parole bien exprimée vaut et dans certain cas surpasse l'artefact même à laquelle elle se réfère."

[20] The definition of *fabrica* at Vitruvius 1.1.1 hints towards tacit knowledge, with the crucial difference that *fabrica* is described very much in terms of individual experience, whereas tacit knowledge, as we are discussing it here, implies a community.

[21] Vitruvius 1.1.18: "Namque non uti summus philosophus nec rhetor disertus nec grammaticus summis rationibus artis exercitatus, sed ut architectus his litteris imbutus haec nisus sum scribere. De artis vero potestate quaeque insunt in ea ratiocinationes, polliceor, uti spero, his voluminibus non modo aedificantibus, sed etiam omnibus sapientibus cum maxima auctoritate me sine dubio praestaturum." Cf. Novara (2005), 125-6.

[22] E.g. Romano (1987), 81-7, indirectly qualified at 97-8 but also by the passage 6.preface.3-4 cited on p.168; see also Gros (1994), 86; Novara (2005), 11.

[23] Vitruvius 10.8.6: "Quantum potui niti, ut obscura res per scripturam dilucide pronuntiaretur contendi, sed haec non est facilis ratio neque omnibus expedita ad intellegendum praeter eos qui in his generibus habent exercitationem. Quodsi

qui parum intellexerit ex scriptis, cum ipsam rem cognoscet, profecto inveniet curiose et subtiliter omnia ordinata."

[24] Cf. Vitruvius 6.3.11. See also *usus* in contrast to e.g. *symmetria*, 5.6.7, and the similarity between this passage and that on catapults in book 10, where, after a list of relative specifications (all relative to a module), Vitruvius says that to these proportions one applies *adiectiones* and *detractiones* (10.10.6).

[25] Vitruvius, 6.2.1, 4: "Nulla architecto maior cura esse debet, nisi uti proportionibus ratae partis habeant aedificia rationum exactiones. Cum ergo constituta symmetriarum ratio fuerit et conmensus ratiocinationibus explicati, tum etiam acuminis est proprium providere ad naturam loci aut usum aut speciem <detractionibus aut> adiectionibus temperaturas <et> efficere, cum de symmetria sit detractum aut adiectum, uti id videatur recte esse formatum in aspectuque nihil desideretur. [...] Cum ergo quae sunt vera falsa videantur et nonnulla aliter quam sunt oculis probentur, non puto oportere esse dubium quin ad locorum naturas aut necessitates detractiones aut adiectiones fieri debeant, sed ita uti nihil in his operibus desideretur. Haec autem etiam ingeniorum acuminibus, non solum doctrinis efficiuntur." On *detractionibus aut adiectionibus* see Callebat's commentary to the Belles Lettres edition, 90. On the relevance to

these issues of the notion of *kairos*, see Corso & Romano's commentary *ad locum* to their Italian translation, *cit*. Cf. also Vitruvius, 5.6.7.

[26] Vitruvius e.g. 1.2.3, 1.3.2, 2.3.4, 2.8.1, 3.3.13, 3.5.11, 4.1.6, 4.2.2, 5.1.10, 6.3.11, 7.preface.18. Cf. also *elegans:* 1.2.2, 1.3.2; *voluptas* (1.2.2); *decor.* 1.2.4.

[27] E.g. Vitruvius 5.6.7, 6.2.1, 6.3.11, 10.16.12, or see the pairing with *disciplina* at 1.1.3. On *sollertia* see e.g. Romano (1987), 166-7.

[28] This adumbrated by Fleury, e.g. (1994), 202-3 and (1996), 60, except that he thinks that the machines do work.

[29] This does not negate the fact that Vitruvius is aware of the crucial role played by writing in the transmission of knowledge: see above all 7.preface.1-3. Nevertheless, all the examples in that passage are about knowledge-that (history, physics, philosophy) and its insistence on *memoria* chimes in with the emphasis in the modern literature on tacit knowledge on loss of knowledge through failed mechanisms of transmission, see e.g. MacKenzie & Spinardi (1995).

[30] Meißner (2003), 153. Cf. also the remarks in Formisano (2001) chapter 2.I.

[31] Cf. Novara (2005), 20-34 for a different kind of claim about the presence of the author.

[32] Vitruvius 1.1.15: "Igitus in hac re Pytheos errasse videtur quod non animadvertit ex duabus rebus singulas artes esse compositas, ex opere et eius ratiocinatione,

ex his autem unum proprium esse eorum qui singulis rebus sunt exercitati: id est

operis effectus, alterum commune cum omnibus doctis" – echoes of the

distinction between the signified and the signifier at 1.1.3.

[33] Vitruvius 1.1.2: *litterae* do not necessarily help you do a better job, but without

them you do not get *auctoritas*=recognition or prestige. The idea that even very

good architects may lack *auctoritas* basically through no fault of their own

emerges again at 3.preface.1. Cf. also on *auctoritates* Vitruvius 5.preface.1.

[34] Vitruvius 1.preface.2: "Itaque cum M. Aurelio et P. Minidio et Cn. Cornelio ad

apparationem balistarum et scorpionum reliquorumque tormentorum refectionem

fui praesto et *cum eis* commoda accepi" (italics mine). In book 2, when he talks

about origins, he indicates as a milestone the moment when, having reached a

certain level of proficiency in building, the people who were more engaged and

keen on building identified themselves as builders (*fabros*, 2.1.6).

[35] Vitruvius 6.preface.5-7, see also 3.preface.3. *Patres familiarum* also at

10.preface.2. Cf. Romano (1987) 181; with more qualifications Novara (2005), 17;

cf. also *ibid.* 157-9 on *le retour à l'action* implicit in the last book, 166-7.

[36] E.g. *décor* at Vitruvius, I.2.5, see the remarks in Geertman (1994), 21-2.