Learning mathematics and science in the ancient Middle East

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I am not a specialist in science education in the modern world; rather, I look at the very beginnings of science education in the Middle East, 5000–2000 years ago. I cannot cover all three thousand of those years in this paper, so instead I shall present two examples of my work, and explain why I think it is important for today's students of science to understand the very ancient history of science and mathematics in this region. The role of science and mathematics in the medieval Islamic world, starting in the 'Abbasid court of Baghdad in the 9th century CE, is already well known, but science and mathematics have a much, much older history in the Middle East, starting from the origins of culture, civilisation and cities five thousand years ago.

I have a rather strange job: I am an archaeologist of mathematics and science. Archaeology essentially is the study of rubbish—the things that other people have abandoned and left behind—in order to discover how those people lived and died, how and why they made and used objects to work with and think with. Like any other human activity, mathematics and science leave trails of rubbish behind. I study the mathematical and scientific rubbish of the ancient Babylonians (and Sumerians and Assyrians), who lived in Iraq many millennia ago. These cultures happen to have left a particularly full trail of physical evidence for archaeologists to excavate. Historians like me, who work on the languages and the thought, can then use that evidence to re-capture the thinking and practices behind some of the world's oldest science and mathematics.

What is now the country of Iraq went by various different names in ancient times (Figure 1). The area south of modern-day Baghdad was known as Babylonia, after its main city Babylon; further south, towards the marshes at the head of the Gulf, was Sumer. To the north, on the upper Tigris, was Assyria, an empire founded by the inhabitants of the city of Assur. The region as a whole is often referred to as Mesopotamia, a Greek name meaning 'the land between the rivers'. But as that was not a term the Babylonians, Sumerians or Assyrians themselves used, I try not to use it either.

Figure 1: Map of ancient Iraq (E. Robson)

Southern Iraq is where the world's first cities began to develop some 6000–5000 years ago, along with the first writing, mathematics, science, law, and literature. In this paper I shall focus on just two periods, though: the so-called Old Babylonian period, c.2000–1600 BCE, from which we have a great deal of mathematical evidence, and the Late Babylonian period, about a millennium and a half later (c.600–200 BCE), when standard histories of science focus exclusively on the ancient Greeks and Romans. But, as I shall show, science was thriving in the Middle East then too. We will see too how influential these scientific and mathematical ideas and practices were, and that they had—and still have—very long afterlives, in both Europe and the Middle East even today.

Ancient Iraq

Southern Iraq is an extremely flat land, formed from the alluvial deposits of the Tigris and Euphrates rivers, and highly fertile when properly irrigated. In her paper Princess Sumaya has suggested that human resources matter more even than natural resources to a regions' success and prosperity. That was certainly true in the very ancient past, for southern Iraq has little in the way of wood, stone, or metals and yet it was home to some of the greatest early civilizations in the world. Of course, we know now that Iraq is extremely rich in oil, but as its extraction and exploitation depend on technologies that have developed only in the past 150 years, oil would have been of little use to the ancient Babylonians. Instead, the inhabitants of Babylonia were very ingenious at exploiting what the land and the water — rivers, canals, and marshes — had to offer them: primarily clay, plants, and animals.

Five thousand years may seem like a very long time ago, but it is very, very recent in relation to the long history of human development. Physiologically and intellectually, the ancient Babylonians were no different to us moderns: they had the same bodies and the same brains as we do. But their technologies were very different, as were their living environments, and these factors inevitably shaped the ways in which they made sense of the world. So at times the Babylonians seem tantalisingly familiar to us, at other times unfathomably strange.

Our evidence is plentiful, almost too plentiful, because the Babylonians used their very fertile clay earth to create writing materials which have endured for thousands of years. The ancient Egyptians, by contrast, wrote on papyrus, made from plant materials, which survives only in exceptionally dry conditions which prevents it from rotting. So although we know little bits about ancient Egyptian science and mathematics, thanks to a few dozen surviving manuscripts, for Babylonia we have literally thousands of ancient clay tablets to work with, ranging in size from a few centimetres across to the dimensions of a big book, and even large monuments many metres high.

The Babylonians wrote on their tablets by pressing a reed stylus into the surface of the clay. Their cuneiform ('wedge-shaped') script is very complicated. It is not an alphabet but a mixed system of syllables and whole words comprising about 600 different characters. But underneath that visual complexity are two very beautiful languages called Sumerian and Akkadian. While Sumerian has no known linguistic relatives, Akkadian belongs to the same language family as Arabic, to which it is very similar. Today we often represent cuneiform writing in modern alphabetic scripts, to make it easier to comprehend. In ancient times most people did not read or write, however, and perhaps that is just as well, given the huge number of writings that do survive. Professional writers, or scribes, were rather like secretaries. They could also be relatively low-status warehouse book-keepers or high-status priests or royal advisors.

Most of what scribes wrote, perhaps as many as 95% of surviving tablets, involved numbers in some way, because cuneiform writing was primarily used to keep track of what people and institutions owned and owed. However, over the millennia writing was increasingly also used to record more abstract ideas about how the world worked. Our sources of ancient thought include students' exercises, written down as they were learning how to write, think, and calculate; learned, scholarly works written in standardised 'library' formats; and the day-to-day correspondence of the scholars themselves in the form of letters, queries, and reports to patrons, clients and colleagues.

These ancient written materials are all archaeological artefacts — that is, objects dug from the ground, ideally during formal excavations documented by archaeologists. That means that we can often reconstruct the contents of ancient Babylonian libraries, schools, offices and other contexts in which writings were made and stored. This methodology is virtually impossible for other ancient civilisations, such as Greece, Rome and Egypt, because almost no original documents survive. Cuneiform tablets, by contrast, constitute first-hand evidence. Even so, there are whole periods and regions of Babylonia about which we know almost nothing, because the distribution of evidence is dependent almost entirely on where archaeologists choose to dig, and what has survived in those places. We know too (because they mention them in tablets) that the Babylonians used writing materials such as papyrus, parchment, and wooden boards, which almost all disintegrated a long time ago. Nevertheless, a great deal of written evidence does survive. And because we have not only the documents but the contextual information, we can get a much richer view of what people did and how they thought, and can begin to answer questions about why they wrote and thought in a particular way. In the rest of this paper I shall present two examples, based on my own research.

The mathematics of justice in the 18th century BCE

Many people imagine that although mathematics has a past, it does not have much of a history. That is, because numbers and other mathematical objects do not change, mathematics in the past might not have been terribly different from mathematics today. Writing the history of mathematics, in this view, just constitutes identifying the circumstances of mathematical discoveries, in order to explain how and when we have come know particular mathematical facts. However, the history of mathematics turns out to be much more interesting than that. Perhaps self-evidently, mathematics looks very different from culture to culture: it is written in different languages and scripts, on different writing media, and may even use different number systems. Less intuitively, however, if we ask what people think about mathematics, what constitutes mathematics, and what mathematics is good for, we discover that the answers to those questions are also very variable from culture to culture. The history of mathematics thus aims to describe and account for these cultural variations across the world. With those thoughts in mind, let us look at what mathematics meant in Babylonia, nearly four thousand years ago.

At first sight Babylonian numbers look very different to the modern Western and Arabic ones because they are made up of wedges pressed into the clay, and because they are in base 60, not base 10. But in fact they are conceptually very similar. Where we use ten digits, the Babylonian system comprises nine unit signs and five tens signs that can be combined in different ways to write numerals up to 59. Then these number signs 1–59 can in turn be strung together to write numerals of any length. In other words, both the Babylonian number system and our own are based on positional principles: the order in which the number signs are written is significant. For instance, in the decimal system the numeral 36 (three tens and six units) is smaller than the numeral 63 (six tens and three units). Similarly, in base 60, the numeral 1 24 means 1 sixty, 2 tens and 4 units (= 84) but 4 21 means 4 sixties, 2 tens and 1 unit (= 261). Even though both numbers are composed of identical signs they have different values because of the relative positions of the signs within the numeral. Positional number systems are very valuable mathematical and scientific tools, for it means that there is no practical upper or lower limit to the magnitude of the numbers one can write or calculate with.

And of course base 60 is itself quite familiar to us too: we still count sixty minutes in a hour and sixty seconds in a minute, and measure angles in multiples and fractions of 60. This is essentially because in the second century BCE Greek astronomers adopted base 60 from Babylonia (transcribed into alphabetic scripts), along with the positional principle, because their own number system was not as suited to astronomical calculations. And although we too use our own scripts and writing media—we don't write time and angle measurements in cuneiform on clay—we think about those base 60 numbers in essentially the same way as the Babylonians did.

So, despite the very different recording methods, Babylonian and modern number systems are not too dissimilar. But the conceptualisation of the basic building blocks of Babylonian mathematics could be very different indeed. For instance, Figure 2 shows the front and back of a large cuneiform tablet from ancient Babylonia now in the British Museum. It has been pieced together from fragments, because it was broken into pieces many hundreds or thousands of years ago. But although a lot of it is missing, from another perspective it is actually rather amazing that so much has survived the four millennia since it was written. On the front there are multiple images of triangles, squares and circles: figures that look very familiar to us from modern mathematics. But on the back there are some rather stranger combinations of shapes for which have no modern geometrical terminology. The texts underneath each of these images are mathematical questions or problems to be solved. For example, the text highlighted on the reverse reads:

> The side of the square is 60 rods. Inside it are: 4 triangles, 16 barges, 5 cow's noses. What are their areas? (from BM 15285, trans. E. Robson)

Figure 2: An Old Babylonian geometry textbook, c.1750 BCE, front and back (BM ME 15285, courtesy of the Trustees of the British Museum, London)

The triangles, it turns out, are the outer corners of the squares, whose longest sides are formed by the quarter-arcs of the circles.

The edges of the 'barges' are the intersecting quarter-arcs of the circles—which look very similar to little clay models of boats found in excavations of Babylonian cities (Figure 3a).

Figure 3a: An Old Babylonian clay model of a boat (Ash 1931.181, courtesy of the Visitors of the Ashmolean Museum, Oxford)

Finally, the 'cow's noses' are the central elements of the circles—what is left when the 'barges' are removed. Ancient Babylonian depictions of bulls and cows (Figure 3b) also show very stylised noses composed of quarter-arcs of circles. Thus these mathematical objects are inspired by important objects in the everyday Babylonian environment: the boats on the rivers and canals, the animals in the herds in the fields.

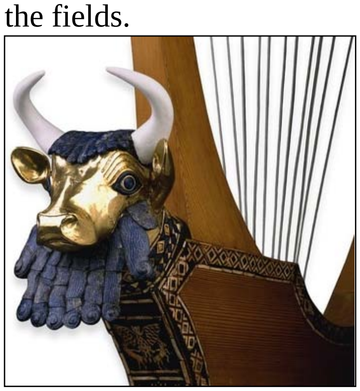
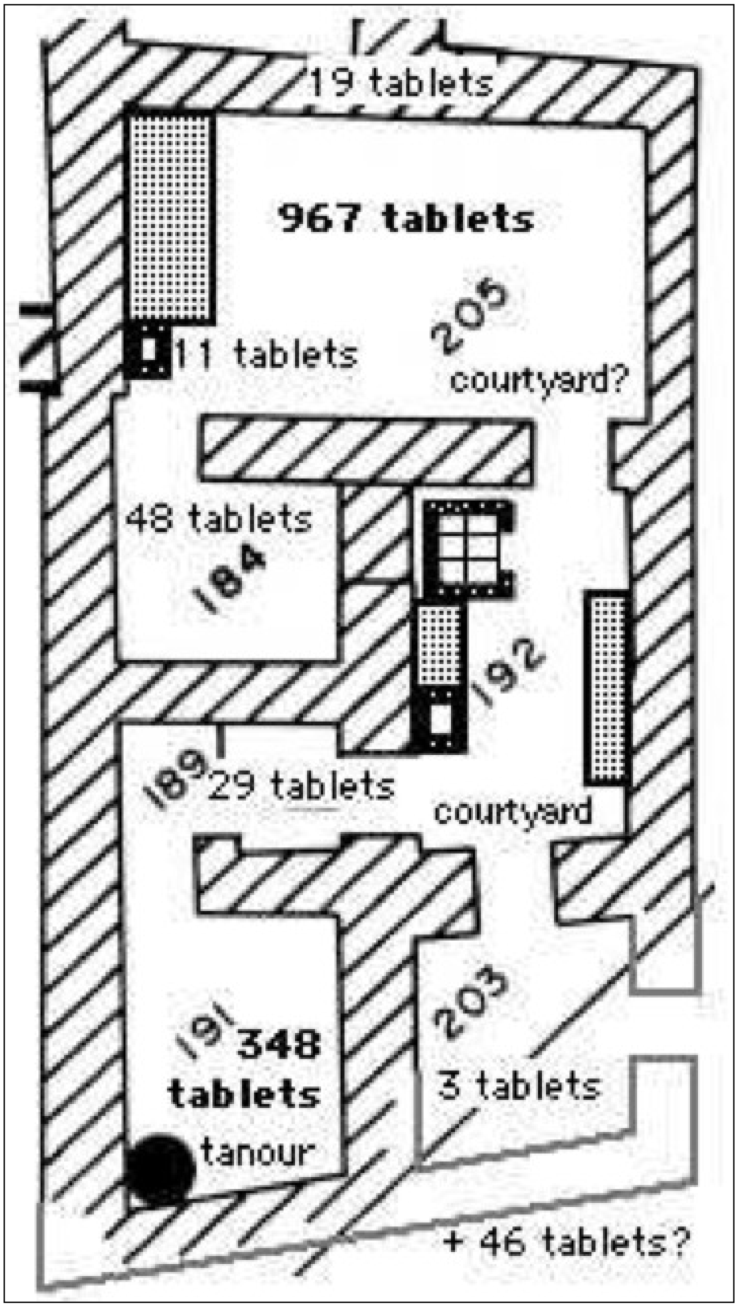


Figure 3b: Detail of the decoration on a Sumerian harp, c.3500 BCE (detail of BM , courtesy of the Trustees of the British Museum)

So what did the Babylonians do mathematics for? Who might have written a tablet like this and why? To answer this question, we shall look at tablets discovered during the excavation of a tiny little house, dating to about 1740 BCE, in the Babylonian city of Nippur some 150 km south of modern-day Baghdad (Figure 4).

Figure 4: Excavation plan of House F in Nippur, c.1740 BCE (E. Robson)



Inside it, the excavators found the usual household documents and objects and, much more unexpectedly, nearly 1500 fragments of school exercises. They had been written on clay and then cut up and re-used as tiny bricks, built into the walls and floor and furniture of the house. Because the excavation took place in 1951, when archaeological objects were still allowed to leave Iraq, the tablet fragments were shared between three museums, in Chicago, Philadelphia and Baghdad and never studied as a coherent group. I spent several years in the late 1990s and early 2000s trying to reconstruct the individual tablets, and piecing together the assemblage as a whole. After September 11, 2001 it became impossible to return to Iraq, so my work is still not finished, but nevertheless it is possible to draw several conclusions about what went on in this house, and why the tablets were written.

The architecture of the house is very ordinary. At the front is a kitchen with a bread oven, at the back a large private family room. But in the middle is a little courtyard where trainee scribes, perhaps the children of the house, learned how to write, count and calculate. The two black square areas are bitumen-lined bins where old tablets were thrown in order to be soaked and re-used. The children started their education by learning how to make tablets and hold a stylus, and how to make the basic elements of cuneiform script: horizontal, diagonal and vertical wedges in the clay. They then learned how to write whole signs, people's names, the names of objects made of different materials, in a very standardised order. There was a lot of very boring memorisation involved: the students wrote out the same exercises again and again until they had learned them by heart. It was probably couple of years into their schooling before they began to learn how to write numbers, weights and measures, and how the base sixty system worked. They worked their way through a long set of multiplication tables in base 60, starting with the largest numbers first: 50, 48, 45, 40, etc., finishing with the two times table, which must have been very easy by comparison. After this, the students moved on two writing whole sentences and texts, in the form of model letters, legal documents, proverbs and sayings.

We can reconstruct the curriculum in such detail because on some tablets a very competent writer—presumably the teacher—would write out a short text in very elegant script on the left hand side, and someone who was not quite so good at writing—the student—would attempt to copy it on the right.

The student could erase their attempt, and write and rewrite as necessary. Then they would turn the tablet over and on the other side write out a much longer passage something they had memorised earlier. By correlating the two sides of the tablets, across the whole assemblage, it was possible to reconstruct the standard order of learning.

After this probably rather long elementary phase, the students in the house began to put mathematical facts into practice by drawing geometrical figures and calculating their areas, just as the tablet in Figure 2 asks for. (This particular tablet is not from our house but it is clear that the teacher there set similar exercises.) At the same time, the children wrote out short extracts of Sumerian literary works, chosen not just for their poetic merit but because they carried important messages about appropriate behaviour for professional scribes. Some are very funny, especially the dialogues between students who are learning how to write and count. Here, for instance, an older student berates a younger one for his incompetence in measuring a field which two brothers have inherited, and his inability to divide it fairly between them:

> (Girini-isag speaks): "You wrote a tablet, but you cannot grasp its meaning. […] Go to apportion a field, and you cannot even hold the tape and rod properly; you are unable to place the field pegs; you cannot figure out its shape, so that when wronged men have a quarrel you are not able to bring peace but you allow brother to attack brother. Among the scribes you (alone) are unfit for the clay. What are you fit for? Can anybody tell us?"
>
> (Enki-manšum replies): "Why should I be good for nothing? When I go to divide a plot, I can divide it; when I go to apportion a field, I can apportion the pieces, so that when wronged men have a quarrel I soothe their hearts and […]. Brother will be at peace with brother, their hearts [soothed]." (from Vanstiphout, H.L.J. 1997. Sumerian canonical compositions. C. Individual focus. 6. School dialogues. In The context of scripture, I: canonical compositions from the Biblical world, ed. W. W. Hallo, 588-93. Leiden: Brill, page 589.)

The moral of the story is that mathematical incompetence leads to unfairness and dispute, where as good mathematical practice brings about peace and social justice. This theme runs through many of the literary works in the house. It tells us that Babylonian scribes saw mathematics as a tool for ensuring justice and fairness in the world.

This idea was current not just amongst the scribes but amongst political and religious leaders too. The most powerful visual images of kings from this period depict them accepting measuring equipment—a ruler, and a rope for measuring fields— from the gods as symbols of their commitment to mathematically administered justice. In the city of Mari, king Zimri-Lim had an image of this scene painted above his throne, so that every visitor to his throne room in the palace was reminded of his divinely ordained duty (Figure 5a).

Figure 5a: Detail of wall painting in the throne room at Mari, showing the goddess Ištar giving the tools of mathematical justice to king Zimri-Lim. c. 1760 BCE (courtesy of Librarie Paul Geuthner)

Similarly, royal inscriptions of the period explicitly state that the gods gave kings and scribes the ability to write, count and calculate in order to bring about social justice.

Figure 5b: Detail of the Codex Hammurabi, showing the god Šamaš giving the tools of mathematical justice to king Hammurabi, c.1760 BCE (Louvre Museum, K. Radner)

Most famously, king Hammurabi, who united the whole of Babylonia under his rule in about 1760 BCE, commissioned a huge monument now known as the Codex Hammurabi (Figure 5b).

The upper surface shows him receiving the symbols of mathematical justice from the sun-god, who saw all human activities as he crossed the daytime sky and therefore also served as the god of justice. Below this image is a long text. The introduction affirms Hammurabi's intention 'for the strong not to oppress the weak' while many of the 280 laws set out fair payments for goods and services, proportionate distribution of land and inheritance, and punishments for those who transgressed those ideals. For instance,

> If a merchant gives grain or silver as an interest-bearing loan, he shall take 100 *sila* per *gur* (= 33%) as interest; if he gives silver as an interest-bearing loan, he shall take 36 grains of silver per shekel (= 20%) as interest.
>
> Law 108: If a (female) innkeeper refuses to accept grain for the price of beer but accepts only silver measured by the large weight, thus reducing the value of beer in relation to the value of grain, they shall establish the guilt of that (female) innkeeper and they shall throw her into the river. (trans. E. Robson)

Now we see why mathematics, and in particular the geometry of lines and areas, was such an important element of scribal training in the eighteenth century BCE. Mathematics encapsulated a very central component of Babylonian thought at this time: the principle that society should be fair, that mathematics was a tool for ensuring justice, and that it was the duty of kings and scribes to use it for the good of society.

Searching for science in the past

Let us now going to to turn to a period over a millennium after king Hammurabi's reign, when most famously Greek science was beginning to develop. At this time Babylonian science continued to flourish too, in very different ways to in ancient Greece. But we get very mixed messages about it: some historians say that the Babylonians were the world’s first great astronomers, others that they were superstitious magicians, dream interpreters, and astrologers who worked only with unprovable (non-scientific) principles. Partly this image comes from the Greek tradition, which found many ways to portray Babylonian scholars in a negative light—while, as we have already seen, adopting the Babylonian number system, and much else of their astronomical and scientific work. As we shall see, it turns out that both images are true, but that neither is the whole truth, and they are—surprisingly—mutually compatible.

It is rather misleading to suppose that we can and should separate science from superstition in the study of the past. Let me give you a more recent example. Perhaps we are all brought up on the idea that the English man Isaac Newton (1643–1727) was one of the founders of modern science. He discovered the laws of motion and universal gravitation, explained how light could be refracted into seven different colours, and developed the profound mathematical techniques of integral and differential calculus. For all these reasons, Newton is portrayed, especially in England, as a heroic genius, a founder of modern science. And yet there is another side to him, which popularising works do not often talk about. For instance, he was also a fanatical alchemist—an illegal occupation in England by his time—with a long-term secret quest to turn base metals into gold. He also had some very strange views about the Christian Bible which, had he published them, would have led to charges of heresy and possible execution. He spent at least as much time on these 'superstitious' activities as he did on doing 'scientific' physics and mathematics, and they are just as much a part of his intellectual character as the works that we now find useful. In other words, to fully understand Isaac Newton we cannot label him simply as a mathematical genius or a hero of physics; but nor should we dismiss him as a lunatic and a dangerous heretic. Rather, we must acknowledge both sides of him, and try to understand him on his own terms.

In other words, when looking for 'science' in the past, whether in Babylonian times or in Newton's, we must not assume that 'science' was the same entity then as it is now. Modern 'science' is carried out by professional scientists, who are trained and work in universities, laboratories and research centres. They have formal qualifications and career structures; they group themselves into specialist disciplines; they disseminate their findings at conferences and in peer-reviewed journals; and are heavily dependent on institutional, national, and international funding. But this system, natural as it may seem now, only came into being in the 19th century. The English term 'scientist' was first used in the 1830s, while Newton described himself as a 'natural philosopher': a philosopher of nature. In this light, it is not surprising that in the past we find very different ways of thinking about the world, because the infrastructures for doing so were also very different.

It very tempting to distinguish between what ancient scientists (whether Newton or the Babylonians) *knew* and what they *believed*. When we say, 'the Babylonians knew that diseases could be infectious' we imply that they were right to do so, according to our own understanding of disease transmission. However, when we say 'the Babylonians believed in witches', the implicit message is that they were wrong to do so (by our standards). It would sound nonsensical to say, for instance, that 'Newton believed in gravity' because we—thanks to Newton—accept that gravity is a real phenomon in the world, unlike witches. But for a Babylonian, witches were a real phenomenon in the world as well; he might argue that both gravity and witches are invisible, but their effects can be directly observed.

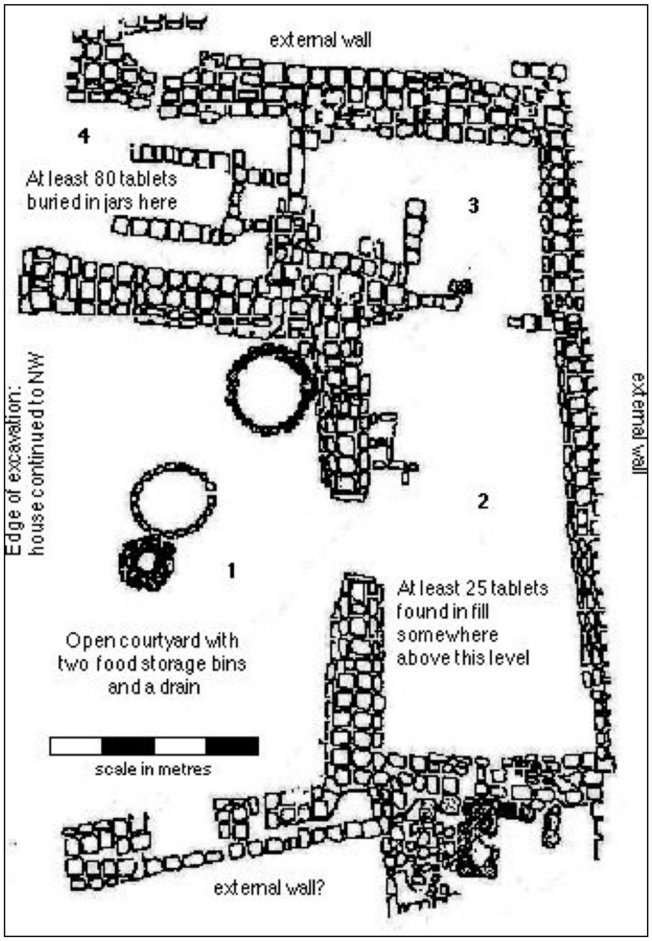
If the history of science concerned itself only with past thinking that we judge to be correct by today's standards, there would be very little to study, even from the 19th and 20th centuries—and the subject matter would be constantly shifting as new theories were proved or disproved. Instead, it is more interesting and useful to examine how and why past thinkers have thought about the natural world in particular ways, regardless of their correctness. This non-judgemental view of the past helps us to better understand how science, and the scientific world, has been shaped into what it is today.

A medical library from the 5th century BCE

With that thought in mind, let us now return to Babylonia in the 5th century BCE, when Babylonia was no longer independent but had become a small but important province of Persia. The Persian Empire was the world's largest at this time, and absolutely enormous compared to Greece. By now many people in Babylonia spoke Aramaic or Persian (the direct ancestor of modern Farsi), writing them in alphabetic script, or simplified cuneiform, on leather rolls and wooden writing boards which no longer survive. But Babylonian scholars still chose to speak and write the traditional Babylonian way, on durable clay tablets. We must always remember that our view of the intellectual world of the Late Babylonian period, as it is known, c.600–200 BC, is thus much more partial than for the Old Babylonian period over a millennium earlier, because so much was recorded on objects that were not designed to last.

Once again, let us focus on a single house. This one was excavated in the city of Uruk in southern Iraq, by a German team in the late 1960s. As before, there is nothing special in the architecture to distinguish it from the houses of other well-off urban families of the time (Figure 6).

Figure 6: Excavation plan of the *āšipus'* house in Uruk (E. Robson)



There is a central courtyard, food storage facilities, an oven and a well. But the archaeologists also discovered a library of about 400 clay tablets, stored in large jars in a back room of the house, as well as a substantial number of household documents. These tell us that the family traced their ancestry to a man called Šangû-Ninurta, and that at least four generations lived here, until about 420 BCE. The library itelf contains works across a wide range of (modern) genres:

- 30% medical (physiognomic and diagnostic omens; medical prescriptions and incantations);
- 20% other incantations, rituals, and magic;
- 19% hymns, literature, and lexical lists;
- 12% observed and induced omens (celestial, terrestrial, extispicy, etc.);
- 12% astronomy, astrology, and mathematics;
- 7% unidentified.

I am currently running a research project, based in Cambridge and Philadelphia, and funded by the UK Arts and Humanities Research Council. My team and I are studying this library, along with four others, to better understand the social and political contexts of Assyrian and Babylonian science.

The men of the Šangû-Ninurta family took the professional title of *āšipu*. This Babylonian word is hard to translate: doctor, exorcist, priest, and healer are all rough approximations. For these men, what we think of as medicine and magic were simply different approaches to the same problem: how to cure illness and help people to get well. For they understood that illness came about through divine anger: angry gods could cause illness or discomfort, either directly or through demons whom they sent to inflict unhappiness and suffering on people. It was the *āšipu's* role to soothe the sufferer's physical symptoms, to drive away the demons, and to calm the gods' anger with the patient. We have a wide variety of textual and physical evidence for these ideas and practices, such as little stone amulets that pregnant women wore around their necks to protect themselves. The amulets depict fierce but benign monsters who were thought to scare away the demoness Lamaštu who snatched (and killed) new-born babies and women in labour.

In a series of rituals and incantations against Lamaštu, stored in the Šangû-Ninurta family's library, the *āšipu* speaks these words on behalf of a woman who has miscarried:

> "I became pregnant (but) did not deliver soundly; I gave birth (but) did not engender. May the conciliable one appeal for me and may those favourable words impregnate(?) me! May I have a normal childbirth and let me get ready! I am the one sitting in the house."
>
> You speak thus three times and you libate first-class beer with parched-grain flour in front of Šamaš; you place the *buqāmu*-lamb that she sits on her lap; it feeds at her breast; and you place the effigy of the god Anu's daughter and whatever else you had brought inside a boat; you make

> (it) cross to the opposite bank of the river; you surround (the woman) with a magic circle and you recite the (following) incantation:
>
> "Mountains and rivers, seas and massive stones, heaven and earth, the god ... whom the god ..., his father, had engendered ..." (from *SpTU* 3, 84, trans. M.-F. Besnier)

These very strange instructions sit alongside more apparently comprehensible texts, such as this one against the ill-effects of sunstroke:

> (If) a person's breathing is burdensome (and he has) diarrhoea: sunstroke [...]. In the morning, on an empty stomach, you wipe out his mouth with *nīnû*-plant. You pour alum into his nostrils. [...]. He sucks mountain honey (on) his tongue.
>
> You wash it (his mouth) with cucumber juice, hound's-tongue (and) tamarisk [...]. You crush together (and) sieve foliage of tamarisk, juniper, *kukuru*-tree (and) foliage of liquorice. You mix (them all) with fat. You press out (the liquid) with leather. You bandage and he will recover. (from SpTU 1, 44, trans. P. Clancier)

While we may not be able to identify every ingredient of this recipe, it is easier for us moderns to identify it as 'scientific' or 'medical', because it reads rather like a more modern prescription, with no mention of divine causation. But the gods are present, nevertheless, as the following extract shows. Here, the same sorts of symptoms—stomach pain, heat stroke—are attributed to the touch of a god, and a prognosis given for each.

> (If) he is ill for 1 day and his head hurts him: heat stroke; hand of the god of his father; he will die.
>
> (If) he is ill for 1 day and he continually puts his hands on his belly, cries out in pain (and) continually stretches out his hands: he will die.
>
> Ditto ((If) he is ill for 1 day) and he continually puts his hands on his belly (and) sucks his fingers: hand of the great gods; he will die. (from SpTU 1, 37, trans. P. Clancier)

Here we see the natural and supernatural worlds intertwined. In the first instance, it seems that the sufferer has angered his father, causing the god whom his father worships to give him sunstroke. He must placate both father and god to avoid the predicted outcome of death.

Looking after people could also involve preventing illness and upset, through performance of ritual and incantations. In the following example, the medicine works to make people nice to the *āšipu's* client, wherever he goes.

> For overseeing ... in the presence of his countrymen, as well as for being honoured over his countrymen, and ... for being agreeable wherever he goes, (use) the stones for sweetening the words of his adversary.
>
> (You thread) these ... (previously mentioned) stone beads on a string of linen, a string of red-purple wool and a string of blue-purple wool. You wrap ..., pure-plant, wood(-for)-releasing, Sun-plant and *tarmuš*-plant, these 5 materials, and ... and red-purple wool, between each (bead). You put them at each side of the bed. (from SpTU 5, 244, trans. G. Cunningham)

The necklace, made of wool, stones, and plant materials, serves as a sort of charm. In this case it is hung on a bed, but they were often meant to be worn on the body. When archaeologists find jewellery in Babylonian graves, of both men and women, they are not simply decorative but have powerful protective properties too. Each stone was chosen to have a particular beneficial effect, as we know from long lists of semi-precious stones and their healing powers.

Above and beyond its scholarly contents, what makes the Šangû-Ninurta library particularly useful for historical study is that at the end of every tablet is a short text called a colophon, which gives the title of the work it contains, who has written it, why, and for whom. Here are two examples:

> Tablet 45 of the standard series of medical omens, *If a man clutches his head like this*.
> Written and checked against its original. Tablet of Šamaš-iddin, junior incantation priest, son of [Nadin], descendant of Šangû-Ninurta, man of Uruk. Whoever fears the gods Anu and Ishtar shall not [take it away].

> Mathematical problems, *Seed and reeds*.
> Copy of a writing board, written and checked against its original. Tablet of Šamaš-iddin, son of Nadin, descendant of Šangû-Ninurta.

What we see from these colophons and others— over a millennium and a half before Nizam al-Mulk's introduction of the *madrasa* to the world — is that at this time even university-level learning took place within the family. Šamaš-iddin taught his sons Anu-ikṣ ur and Rimut-Anu, and later Anu-ikṣ ur taught his own son Anu-ušallim. Fathers and uncles trained their sons and nephews, who in turn trained the next generation, not just in the Šangu-Ninurta family but in scholarly families across the Babylonian world. (This might also have been the case in the Old Babylonian period too, but as those scribes tended not to write colophons, and mostly left their work anonymous, we will probably never know for sure.)

Zodiacal medicine: holistic 'science'

In the same house in Uruk we find mathematical problems that look at first glance very prosaic: here the problem is to work out how far one can extend an animal pen, given a set number of bricks to pave the new area with:

> 9 hundred baked bricks of 2/3 cubits (c.33 cm) each. I enlarged an animal yard. What is the square side of the new animal yard?

> You go 0;40 steps for each brick. You take 30 each of 15 00. You go 30 steps of 0;40: 20. The square side of the animal yard is 20 cubits (c.10 m).

But the library also contains much more sophisticated mathematical tables, listing many hundreds of pairs of mutual reciprocals: that is, numbers that give the product 60 when you multiply them together. We know the Šangû-Ninurta men produced at least one of these tables themselves, because of one very crudely made tablet, also found in the house, containing some of the calculations needed to make them. Most usefully for us, one of the calculations is wrong—and the same error turns up on the finished table too, confirming that it was newly composed by the family members.

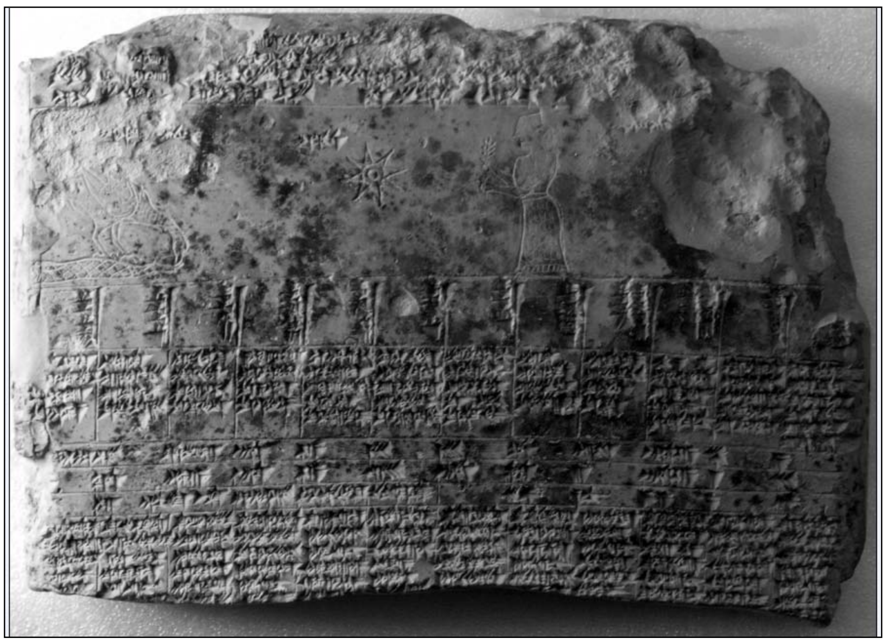
But why should professional healers also be engaged in very complex arithmetic? The fifth century BCE was a time in which medicine, mathematics, and astronomy all began to be linked together, through a new device that we now call the zodiac. Babylonian scholars had already been observing the night sky for several centuries. The world's longest running astronomical observation programme had begun in the city of Babylon in the eighth century BCE and was to continue, month in and month out, for about seven hundred years, eventually resulting in a set of many hundreds of thousands of observational data points. Through systematic analysis of these observations, and the creation of some simple but elegant mathematical tools, the scholars of Babylon developed increasingly accurate models for predicting the movements of the heavenly bodies. They were particularly interested in the risings and settings, conjunctions and oppositions of the sun, the moon, and the five planets that are visible to the naked eye.

Now, these seven celestial bodies all follow the same circuit in the night sky, as seen from the earth: what we now call the ecliptic, and what the Babylonians knew as the Path of the Moon. Some time in the 5th century BCE, Babylonian scholars decided to divide the ecliptic into twelve equal sectors, a division that we now call the zodiac. The did so by looking at the much slower-moving background of stars that appear to be behind the ecliptic, and grouping them into twelve roughly equal constellations, each covering about 30º of arc. Over the course of a night, a new zodiacal constellation rises roughly every two modern hours (one Babylonian hour), shifting slightly every night so that each month one observes a different zodiacal constellation rising at sunset. Over the course of approximately a year, the pattern repeats itself. These twelve zodiacal signs could thus serve as a reference grid, enabling the scholars to describe the positions of the planets in relation to them: one could say that the moon was in 12º Bull, for instance, or the sun in 29º Crab. (The modern zodiacal sign names are almost all direct translations from the Babylonian ones.)

But this was not simply observation for observation's sake: the idea was that the gods had created the world on fundamentally mathematical principles, embedding complex and subtle mathematical patterns within it, such as those encapsulated in the movements of the heavenly bodies. By understanding the mathematical complexities of the divinely created world, one thereby gained a much richer and fuller understanding of the gods and humanity's place within creation. The idea was that if the gods controlled the timings of the night sky in such a sophisticated way, then maybe they also controlled the timings of other natural phenomena that were beyond the control of humankind, and did so in similar ways. Heavenly and earthly events thus became linked in Late Babylonian scholarly thought.

Within medical practice, different types of amuletic stones, aromatic incenses, and healing plants all became associated with particular signs and subdivisions of the zodiac. Now when a person fell ill, the configuration of the stars and planets at that time could be used to help prescribe the most appropriate remedies to treat the patient (Figure 7).

Figure 7: A Late Babylonian tablet, with illustrations of the zodiacal constellations, relating signs of the zodiac to healing materials (Louvre AO 6448 reverse, P. Clancier)



This type of astrological medicine remained popular across Europe and the Middle East until just a few centuries ago. It may not be 'correct' medicine, as we now understand it, because there is no provable causal link between planetary movements and personal illness. But it is nevertheless important to understand how and why it worked, for it shaped perceptions of illness and wellness, and the fundamental structure of the divinely-created universe, across many cultures for at least two millennia.

Conclusions

To sum up, there is a very rich and complex history of thought in ancient Babylonia—and in other regions of the Middle East that I have not been able to deal with here. But why should this matter to students of modern science, who will be shaping our future, rather than dwelling on our past? By looking at the beginnings of intellectual curiosity about how the world works, and why, it help us —and our students—to understand that different people and cultures have many different ways to make sense of the world. Modern ways of thinking have ancient roots but have responded to new evidence, new theories, new tools. Scholars and scientists are constantly coming up with new ideas and methods, and there is rarely only one right answer to any particular problem. Rather, different solutions may be valid in different social and cultural contexts. Being wrong is not a disaster, and being right is often only temporary too: what people consider to be 'correct' science changes dramatically over time, and we should also expect that our ideas will be overturned or improved in due course too. In this light, it becomes much easier to take risks and to try new methods and theories. And, as our first example in particular showed, science and mathematics are not simply tortuous exercises inflicted on students on their teachers, or stimulating intellectual challenges to be relished just for fun. They do have an impact on real people's lives for better or for worse, and—used well—can be powerful tools for social good, economic betterment and political justice.

Further reading: books and websites

B. Foster and K.P. Foster, *Civilizations of ancient Iraq* (Princeton, 2009) is a very nice recent introduction to the region's ancient history. The British Museum's, *Mesopotamia* website (http://www.mesopotamia.co.uk) is a marvellous teaching resource. *ABZU* (http://www.etana.org/abzu) and *The Ancient World Online* (http://ancientworldonline.blogspot.com) are the most comprehensive and reliable portals to other high-quality internet resources on ancient Iraq.

Chapter 4 of E. Robson, *Mathematics in Ancient Iraq: a Social History* (Princeton, 2008) gives an account of the 18th-century mathematics of justice. Translations of many of the original tablets are in the *Digital Corpus of Cuneiform Mathematical Texts* (http://oracc.org/dccmt), along with PDFs of several of my articles on Babylonian mathematics. Some 400 Sumerian literary works are online at the *Electronic Text Corpus of Sumerian Literature* (http://etcsl.orinst.ox.ac.uk).

F. Rochberg, *The Heavenly Writing* (Cambridge, 2004) and J. Steele, *A Brief History of Astronomy in the Middle East* (Saqi, 2007) both cover aspects of Babylonian astronomy and astrology, while M.J. Geller, *Ancient Babylonian Medicine: from Theory to Practice* (Blackwell, 2010) is a recent history of Babylonian medicine. E. Robson, et al., *The Geography of Knowledge in Assyria and Babylonia* (http://oracc.org/gkab) attempts to look at these ancient disciplines holistically, through the study of libraries, and publishes many hundreds of translations of Babylonian scholarly works through the *Corpus of Ancient Mesopotamian Scholarship* (http://oracc.org/cams).

On Isaac Newton, see P. Fara, *Newton: the Making of a Genius* (Macmillan, 2002).