Review of: "Early Renaissance Concepts of Time and the Invention of Mechanical Clocks"

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I have never heard of Qeios before (and neither did the people around me), but I was invited to review this article via the invitation of a colleague. Even though I am a bit skeptical of this platform, the idea of experimenting with the peer review system seems intriguing to me. Hence, because I appreciate the attempt to challenge established norms, I have agreed to write an open peer-review and put some effort into it.

First, I want to say that the engagement with the article has been very inspiring to me. As a historian interested in the mathematical cultures of clockmakers, among others, the paper offered several interesting insights. Not only is the overall argument about a connection between the Aristotelean conception of time and the invention of mechanical clocks in Europe in the 13^{th}/14^{th} century fascinating and constitutes – at least as far as I am concerned – a novel point of view, but there were also a number of technical details from the presentation of the medieval and early modern history of clocks that caught my attention. For scholars in fields such as the history of technology, the findings presented in the article can definitely make it worth a read.

However, even though the paper offers potential with respect to its content, I must add that its main argument still needs to be sharpened, differentiated, and clarified. The structure of the text especially needs some more work to make the claim fully clear and convincing. In the usual terminology, I would thus argue that the paper still needs some major revisions, which is why I gave the article an overall rating of two stars.

In the following, I hence want to offer some suggestions on how to strengthen the presentation of the argument. They come from the perspective of a researcher who once did his master's in physics but has been trained and is now working as a historian of science. My comments are thus less concerned with the technical descriptions of the distinct kinds of clocks, which do not need further substantiation in my opinion, and instead focus on the way of reasoning.

I will start with more general points and then go increasingly into detail. Smaller suggestions that concern specific passages of the text or single words are annotated in the attached pdf. One must be aware, however, that I am neither a native English speaker nor did I specifically check the article for language and style – I just marked the things that struck me while reading.

Concerning the overall structure of the argument, it seems to me that the article makes two more or less distinct claims. On the one hand, it is argued that the prevalence of the Aristotelean conception of time as motion had an impact on the invention of mechanical clocks, especially the “verge-and-foliot-mechanism”. It appears to me – if I take into consideration the title that the author has given to the article – that it constitutes the main claim. (It is also the most interesting one, in my opinion.) On the other hand, the author also offers what might be called a technical history of clocks, culminating in the mechanical explanation that the increased accuracy of pendulum clocks is due to the fact that they are less affected by changes in friction. This last point, however, seems to have already been the subject of a previous paper he co-authored.

In this light, I would urge the author to consider restricting the article to the first argument only. This could make the paper more concise, and it would become much clearer to the reader where things are going. Not only are the two claims concerned with historical periods that are at least three hundred years apart, but their very nature is essentially different. While the first one is of a more historical-philosophical kind, the second one stems from classical mechanics. The merging of these fields can potentially be very fruitful and should be appreciated. In the current version, however, they are merely posited next to each other, rather than interacting productively.

Phrased differently, the question is whether the article wants to portray a history of clocks and their accuracy, or whether – as the title suggests – it is concerned with the connection between the invention of mechanical clocks and a specific conception of time. As it stands now, the article is situated somewhere in between. Here, the author needs to make a clear decision, in my opinion.

Now concerning the first argument. What is yet missing to me is a differentiated formulation of how the connection between the Aristotelean conception of time and the invention of mechanical clocks must be understood, according to the author. As I understand the text, it is argued that the Aristotelean conception of time as motion was prevalent around the 13^{th} century, as attested by the “Condemnation of 1277”, and “the idea of measuring linear time by a periodically oscillating process led to the invention of the mechanical clock.” So basically, in my reading, the author argues for a temporally linear and causal connection between the presence of an idea or notion and a specific technological development.

One needs to be careful here. Although it seems indisputable that the specific conception of time as motion existed prior to mechanical clocks in this context, the relation between them could be framed more as one of co-production than one of causality. (For an explanation of the concept of co-production, although concerned with the interrelation between science and society more generally, see Sheila Jasanoff’s *States of Knowledge: The Co-production of Science and Social Order* (Routledge 2004).) Can we not expect the emergence of mechanical clocks to have also reinforced a specific conception of time? Later on, for instance, the author brings some historical examples of what might have been attempts to construct these kinds of clocks that predate 1277.

But this is just a suggestion. If the author instead decides to stay with a more causal kind of connection, however, the argumentation must be toned down, in my opinion. The evidence is not extraordinarily strong, and the thesis is rather speculative. Furthermore, one should be careful not to reproduce an idealist image of technical development. The prevalence of the Aristotelean conception might have been one of the factors that contributed to the invention of mechanical clocks at that time, but it surely was not the only, and probably not even the most decisive one, as it existed already prior to that.

Moreover, as it stands now, it is not clear what the purpose of the section on sand clocks for the argument is. The point is made that there seems to have been a more general interest in producing accurate clocks from the 14th century onwards, due to the developments in naval technology. But this seems to weaken the argument as it shows that several kinds of clocks were developed at that time, and not only the ones that can be correlated with the Aristotelean conception of time.

Hence, I would propose a restructuring of the argument in the following manner. First, one could show that there was an increasing interest in the production of clocks from the 13th/14th century onward. This could also refer to the social and technological context of that time (going beyond developments in naval technology). The section on the sand clocks can serve as a reference for this occurrence. Second, one could show that at that time, one could encounter the invention of mechanical clocks. Third, one can show that one of the factors that might have contributed to their invention was the specific conception of time that was prevalent. Fourth, the prevalence of this view can be explained, also with reference to the socio-political situation. Did it just become common and important due to the Condemnation, because suddenly it was a matter of contestation?

Such a way of reasoning would both protect the argument from a (too) simplified idealist narrative – the Condemnation of 1277 led to the invention of mechanical clocks – and would also highlight that technological developments are not merely the result of certain social needs or demands. There is always an interplay between material relations and mental conceptions at stake. The case of the invention of mechanical clocks could serve as a convincing illustration in this respect.

There is another more general point I want to mention. I would recommend the author to get rid of all the allusions to scientific developments at that time. This concerns both the points made on Buridan and Oresme as well as on Galileo, Kepler, and Newton. (I highlighted all the passages in the pdf.) On the one hand, making these connections merely distracts from the central argument of the article, rather than strengthening it. On the other hand, these passages contribute to an image of the history of physics that is linear and done by individual geniuses. Not only is this something that most contemporary historians of science would oppose, but it also goes against the claim by the author that it was a certain conception of time that seems to have been common in this culture, instead of a mere groundbreaking idea of one single inventor that led to the development of mechanical clocks.

More specifically, in this respect, I suggest to the author to get rid of the last two paragraphs in the chapter on pendulum clocks. Claiming that clocks had an impact on what could be called the mechanical world view (what the author refers to as the reductionist approach) opens another huge question. While it is a super interesting issue, it would demand a lot more research to be convincingly answered, and there is already a vast amount of literature on this topic. The thesis has already been asserted in the 1930s by Henryk Grossmann, for instance (https://link.springer.com/book/10.1007/978-1-4020-9604-4). In this respect, the author might also be interested in works from the 'practical turn' in early modern science studies, which try to emphasize the role of practitioners in the transformation in the views and study of nature in the 16th and 17th centuries, such as Pamela O. Long's *Artisan/Practitioners and the Rise of the New Sciences, 1400-1600* (2011, Oregon State University Press) or Pamela H. Smith's*The Body of the Artisan: Art and Experience in the Scientific Revolution* (2006, University of Chicago Press).

In the end, I want to make several points that concern single sections of the article.

Introduction

- It would be good to add at least one sentence of social context to the "Condemnation of 1277".

The Condemnation of 1277 and the concepts of space, time, and motion:

- The critique of Alexandre Koyré towards Duhem's thesis does not become really clear from your presentation.
- I agree with one of the other reviewers that the description of the content of the Condemnation can be condensed. Move the paragraph that starts with "The general trend…" in front of the numbered paragraphs. Moreover, include only those parts that are directly relevant to the conception of time, and paragraph two hundred should be mentioned earlier as this is the central argument. Furthermore, in the end, it is referred to Aristotle's conception of time as "an illusion defined by motion". This idea of illusion would need to be introduced earlier and needs elaboration.

The symbolism of the mechanical clock

- Consider deleting this section as it is not directly related to the argument of the article.
- Concerning the clocks in scientific debates, see Gideon Freudenthal's*Atom and Individual in the Age of Newton: On the Genesis of the Mechanistic World View* (1986, Springer), although it is concerned with a later context (Leibniz-Newton debate) and the conception of space.

Mechanics of the verge-and-foliot mechanism

- It is argued that the verge-and-foliot mechanism must be considered to constitute a technological leap in the history of clocks. However, it seems to be merely asserted rather than properly argued why this should be the case.
- The last two paragraphs belong to the next argument about the increased accuracy of pendulum clocks and should be moved accordingly to the beginning of the corresponding section.

Conclusion

- Give a concise summary of the argument about the connection between the invention of mechanical clocks and the Aristotelean conception of time.

To conclude, I want to emphasize that all of the above-mentioned points portray my own opinion. Due to the overproduction of academic texts, I prefer clear-cut and concise arguments to more associative kinds of elaborations. But this can be a matter of taste. Other readers might have different impressions of the text.