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Did Francis Bacon's attitude towards the role of mathematics in natural philosophy change between 1605 and 1623?

As atitudes de Francis Bacon mudaram em relação ao papel da matemática na filosofia natural entre 1605 e 1623?

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ABSTRACT

It is a well-known claim that Francis Bacon gave an auxiliary role to mathematics in his natural philosophical inquiries. It has also been argued that Bacon gave this auxiliary role to mathematics just after he extended the role of mathematics to all parts of natural philosophy in his *De Augmentis Scientiarum* (1623), while he confined its role to metaphysics in his *Advancement of Learning* (1605). In this paper, however, I argue that there is no difference in Bacon's attitude towards the role of mathematics in natural philosophical inquiries between 1605 and 1623.

Keywords: Francis Bacon, pure mathematics, mixed mathematics, natural philosophy.

RESUMO

É uma afirmação bem conhecida que Francis Bacon deu um papel auxiliar à matemática em suas investigações de filosofia natural. Argumentou-se também que Bacon atribuiu este papel auxiliar à matemática logo após ter estendido o papel da matemática a todas as partes da filosofia natural em seu *De Augmentis Scientiarum* (1623), enquanto ele limitou seu papel à metafísica em seu *Advancement of Learning* (1605). Neste artigo, no entanto, argumento que não há diferença na atitude de Bacon em relação ao papel da matemática em suas investigações de filosofia natural entre 1605 e 1623.

Palavras-chave: Francis Bacon, matemática pura, matemática mista, filosofia natural.

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1. Introduction

Graham Rees argues that Bacon has a different attitude towards the role of mathematics in natural philosophy in his *Advancement of Learning* (1605) and *De Augmentis Scientiarum* (1623).[2] For Rees, Bacon placed mathematics as an adjunct of metaphysics in the *Advancement of Learning*. As to *De Augmentis Scientiarum*, Rees argues that Bacon extended the role of mathematics in this work to all the parts of natural philosophy: physics, metaphysics, mechanics, and magic. However, for Rees, this shift was accompanied by a reducing of the role of mathematics to auxiliary.

In this paper, I argue that Bacon placed mathematics as a branch of metaphysics both in the *Advancement of Learning* and *De Augmentis Scientiarum*. Regarding this, I argue that the reason why he placed (mixed) mathematics as a branch of metaphysics is that the object of mixed mathematics, that is, quantity determined, is one of the essential forms of things. Therefore, contrary to Rees' argument, placing mathematics as a branch of metaphysics does not come to mean that Bacon only confined mathematics' role to metaphysics. I will also argue that Bacon gave an auxiliary role to mathematics not only in the *Advancement of Learning* but also in *De Augmentis Scientiarum*. This shows us that his attitude towards the role of mathematics did not change between 1605 and 1623.

2. An auxiliary role for mathematics as a branch of metaphysics both in the *Advancement of Learning* and *De Augmentis Scientiarum*

Let me start with the following quote from Bacon:

> *I have thought it better to designate Mathematics, seeing that they are of so much importance both in Physics and Metaphysics and Mechanics and Magic, as appendices and auxiliaries to them all (Bacon, De augmentis, SEH IV, p. 370).*

Rees argues that giving importance to mathematics both in physics, metaphysics, mechanics, and magic does not appear anywhere in the *Advancement of Learning*. He also states the following:

> *We cannot shut our eyes to the fact that between 1605 and 1623 mathematics had ceased to be regarded as an adjunct of metaphysics; Bacon had shifted his position in favour of acknowledging a much wider role for mathematics in the natural sciences (Rees, 1986, p. 412. See also Rees, 1985, p. 27).*

It follows then that we should ask why Rees believed Bacon limited the role of mathematics to metaphysics in the *Advancement of Learning*. We can find the answer in the following words of Bacon:

> *Neuerthelesse there remaineth yet another part of NATVRALL PHILOSOPHIE, which is commonly made a principall part, and holdeth ranke with PHISICKE speciall and* ***METAPHISICKE****: which is Mathematicke, but I think it more agreable to the Nature of things, and to the light of order, <u>to place it as a Branch of* ***Metaphisicke***</u> *(Bacon, The Advancement, OFB IV, p. 87; underlining added).*

Since Bacon says that he places mathematics as a branch of metaphysics in the *Advancement of Learning*, Rees must have surmised that Bacon confined mathematics' role to metaphysics. However, when we look at *De Augmentis Scientiarum*, we can also see that Bacon placed mathematics as a branch of metaphysics:

> *ARISTOTLE has well remarked that Physic and Mathematic produce Practice or Mechanic; wherefore as we have already treated of the speculative and operative part of natural philosophy, it remains to speak of Mathematic, which is a science auxiliary to both. Now this in the common philosophy is annexed as a third part to Physic and Metaphysic; but for my part, being now engaged in reviewing and rehandling these things, if I meant to set it down as a substantive and principal science, I should think it more agreeable both to the nature of the thing and the clearness of order <u>to place it as a branch of Metaphysic</u> (Bacon, De augmentis, SEH IV, p. 369; underlining added).*

Since Bacon did not say in the *Advancement of Learning* that mathematics had importance both in physics, metaphysics, mechanics and magic, Rees seems to conclude that Bacon confined the role of mathematics to metaphysics in the *Advancement of Learning*. Also, Rees argues that Bacon gave the auxiliary role to mathematics in *De Augmentis Scientiarum* after he extended the role of mathematics to physics, metaphysics, mechanics and magic. However, when we read the following words of Bacon, we can see that he had the idea

[2] Bacon sent a letter accompanying a copy of *De Augmentis Scientiarum* to the King, in which he writes, "This book was the first thing that ever I presented to your majesty […] It is a translation, but almost enlarged to a new work" (Craik, 1846, p. 40).

of the auxiliary role for mathematics in the *Advancement of Learning* as well:

> *MIXT (mathematics) hath for subiect some Axiomes or parts of Naturall Philosophie: and considereth Quantitie determined [the object of mixed mathematics], as it is auxiliarie and incident vnto them (Bacon, The Advancement, OFB IV, p. 88).*

A similar statement can be seen in *De Augmentis Scientiarum*:

> *Mixed Mathematic has for its subject some axioms and parts of natural philosophy, and considers quantity [quantity determined] in so far as it assists to explain, demonstrate, and actuate these (Bacon, De augmentis, SEH IV, p. 371).*

Placing (mixed) mathematics[3] as a branch of metaphysics and giving an auxiliary role to it both in the *Advancement of Learning* and *De Augmentis Scientiarum* refutes Rees' above-mentioned arguments. As Rees states, Bacon only mentioned the importance of mathematics both in physics, metaphysics, mechanics, and magic in *De Augmentis Scientiarum*, but this is not enough to conclude that Bacon did not give the same importance to mathematics in the *Advancement of Learning*. Rees argues that Bacon gave an auxiliary role to mathematics in *De Augmentis Scientiarum* as a result of an extension of the role of mathematics to every part of natural philosophy, but, as I have shown above, Bacon also gave an auxiliary role to mathematics in the *Advancement of Learning*.[4]

What Bacon did in the *Advancement of Learning* (and also in *De Augmentis Scientiarum*) was indeed place mathematics as a branch of metaphysics, and this was wrongly interpreted by Rees as confining the role of mathematics to metaphysics.

Now, what does placing mathematics as a branch of metaphysics mean and why did Bacon do it?

The reason Bacon placed (mixed) mathematics as a branch of metaphysics was that the object of (mixed) mathematics, that is, quantity proportionable (or quantity determined), is a form. As Bacon states:

> *And it is true also that of all other formes (as wee vnderstand formes) it [quantity determined, or proportionable] is <u>the most abstracted, and separable from matter</u> and therefore most proper to **Metaphisicke**; <u>which hath likewise beene the cause, why it hath beene better laboured, and enquired, than any of the other **formes**, which are more immersed into Matter</u> (Bacon, The Advancement, OFB IV, p. 87; underlinings added).*

Also, in *De Augmentis Scientiarum*, he states:

> *For Quantity (which is <u>the subject of Mathematic</u>), when applied to matter, is as it were the dose of Nature, and is the cause of a number of effects in things natural; and therefore it must be reckoned as one of <u>the Essential Forms of things</u> (Bacon, De augmentis, SEH IV, p. 369-370).*

As is seen, Bacon thought that the object of (mixed) mathematics (that is, quantity determined) is one of the essential forms of things, the most abstracted one from matter among other forms. We can therefore conclude that since Baconian metaphysics deals with forms, and since the object of mixed mathematics (quantity determined) is one of the essential forms of things, then there is nothing to be surprised at in the placing of mathematics as a branch of

[3] The term 'mixed mathematics' corresponds to Aristotelian mathematical sciences, which can be considered as falling between pure mathematics and physics. Gary Brown argues that "the term 'mixed mathematics' can be traced back at least as far as Francis Bacon" (Brown, 1991, p. 81). They were also called *exact sciences* or *middle sciences (mediae scientiae)*; see Grant (2004, p. 20).

[4] Bacon states why he gave an auxiliary role to mathematics:

> *Which indeed I am in a manner compelled to do, by reason of the daintiness and pride of mathematicians, who will needs have this science almost domineer over Physic. For it has come to pass, I know not how, that Mathematic and Logic, which ought to be but the handmaids of Physic, nevertheless presume on the strength of the certainty which they possess to exercise dominion over it (Bacon, De augmentis, SEH IV, p. 370).*

Bacon gave an auxiliary role to mathematics because he did not believe that mathematical reasoning or logic could discover the truth of nature, so he offered the priority of physics in natural inquiries. We can say that an auxiliary role of mathematics refers to a priority of physics. A priority of physics is the idea that inquiries into the physical reasons for something should precede mathematical demonstrations of it. Rees also says the following about the priority of physics:

> *According to Bacon the correct geometrical description would emerge only from a correct physical theory, from "inquiries into physical causes" and the truth of things. He insisted on the priority of physics in the business of solving astronomical and cosmological problems, and dismissed the purely descriptive enterprise with its infatuation with compounded perfect circles as a lamentable instance of misapplied effort (Rees, 1986, p. 414).*

Giuliano Mori expresses well the idea of the priority of physics in Baconian natural philosophy: "What is hence at stake is not the mathematization of nature, but, on the contrary, the 'naturalization of mathematics' […]" (Mori, 2016, p. 20). For the mathematization of nature, see Henry (2002, p. 14-30), Biener (2008, p. 9-11), and Goldenbaum (2016). Dana Jalobeanu argues that there is a possibility of a mathematical physics which is peculiar to Bacon (see Jalobeanu, 2016, p. 53-55). The mathematical physics which was used in this peculiar meaning by Jalobeanu should not be confused with the mathematical physics of Copernicus, Galileo and Kepler.

metaphysics.[5] This shows us that, in contrast to the Aristotelian divisions of sciences, mixed mathematics (or mathematical sciences) was considered by Bacon as a part of natural philosophy.

As to pure mathematics, it includes the sciences of geometry and arithmetic.[6] However, mixed mathematics includes mathematical sciences such as perspective, optics, astronomy, and harmony. Pure mathematics deals with quantity (indefinite), which is completely severed from matter and from the axioms (or causes)[7] of natural philosophy, while mixed mathematics deals with quantity (determined) and is not completely severed from matter.[8] Since the object of mixed mathematics is not completely severed from matter, it has some axioms of natural philosophy, which means that the subject of mixed mathematics (quantity determined) is 'causatiue in Nature of a number of Effects.' As Bacon states: "[...] *Quantitie determined, or proportionable* [...] appeareth to bee one of <u>the *essentiall forms* of things</u>; as that, <u>that is causatiue in Nature of a number of Effects"</u> (Bacon, *The Advancement*, OFB IV, p. 87-88, underlinings added). In these words, we can see that the reason Bacon placed mixed mathematics as a branch of metaphysics was that its object is one of the essential forms of things, and this makes the object of mixed mathematics causative of a number of effects in nature.

Just because Bacon did not place pure mathematics in natural philosophy, we cannot conclude that he did not give any importance to it. When we consider natural philosophy, to be classified as a part of it, any discipline has to have some axioms of nature as its subject. Any progress in pure mathematics and logic will be helpful to progress in mathematical sciences, thereby in natural philosophy; but, since pure mathematics deals with quantity indefinite, which is completely severed from matter, it has no axioms of nature, and this makes pure mathematics unsuitable to be classified in natural philosophy.[9] So, the difference between quantity indefinite (the object of pure mathematics) and quantity determined (the object of mixed mathematics) is that while the former is completely severed from matter, which means that it has no axioms of nature, the latter is not completely severed from matter, and this status of quantity determined is the reason it is a causing agent of many effects in nature.

Before proceeding further, let me explain what Bacon means by saying that quantity determined 'is causatiue in Nature of a number of Effects.' Bacon gives some examples to show us how quantity can be the cause of some effects in nature. For example, we can observe that a large quantity of water corrupts slowly, while small quantities of water corrupt quickly. Again, when we consider casks, which can have a larger quantity of wine and beer in them than bottles, these liquids ripen more quickly than they do in bottles. Also, we can see that a large quantity of magnets can draw more iron than a small quantity (see Bacon, *Novum*, OFB XI, Book Two, §. 47, p. 383). Since quantity determined is the cause of many effects in nature, mixed mathematics was placed by Bacon as a branch of metaphysics, which makes mathematical sciences part of natural philosophy.

In the *Advancement of Learning*, Bacon did not mention the importance of mathematics, as Rees states, both in physics and metaphysics and mechanics and magic; however, this does not mean Bacon did not give a role to mathematics in the *Advancement of Learning*, except in metaphysics. In a similar manner, when we look at *De Augmentis Scientiarum*, we see that Bacon does not mention natural history, which is also – alongside with physics, metaphysics, mechanics and magic – a part of natural philosophy. However, we cannot deduce from this that Bacon did not give any role to mathematics in natural history.[10] Natural histories include the observations and records of the motions of celestial bodies, and these observations and records are not possible without the application of mathematics.[11] As you remember, Bacon says that mixed mathematics considers quantity in so far as it assists to explain, demonstrate, and actuate its subject axioms. When we consider mathematical sciences, actuating these axioms can be possible through mathematics. For example, for Bacon, after you develop a physical model of celestial motions, you can develop a mathematical model for it

[5] According to Bacon, while physics is the inquiry into material and efficient causes, metaphysics includes formal and final causes. However, natural philosophy does not include inquiries into final causes because, for Bacon, even though final causes are real, they are barren and beyond human comprehension. So, we can conclude that in Baconian natural philosophy metaphysics is only an inquiry into formal causes. For the classification of sciences in Baconian philosophy, see Anstey (2012) and Kusukawa (1996). For Baconian forms, see Whitaker (1970), Horton (1973, p. 243-244) and Rusu (2013, p. 192-197). On the rejection of inquiries into final causes in Baconian natural philosophy, see Pérez-Ramos (1988, p. 162) and Quinton (1993, p. 160).

[6] Bacon defines the parts of pure mathematics as follows: "These are two, Geometry and Arithmetic; the one handling quantity continued, and the other dissevered" (Bacon, *De augmentis*, SEH IV, p. 370).

[7] Bacon also uses the term 'axiom' for cause, such as 'formal axioms' instead of 'formal causes'.

[8] In *De Augmentis Scientiarum*, Bacon states:

> *Mathematic is either Pure or Mixed. To Pure Mathematic belong those sciences which handle Quantity entirely severed from matter and from axioms of natural philosophy. These are two, Geometry and Arithmetic; the one handling quantity continued, and the other dissevered (Bacon, De augmentis, SEH IV, p. 370).*

[9] Nobuo Kawajiri argues that Bacon gave a handmaiden (auxiliary) role to pure mathematics (see Kawajiri, 1979, p. 17). However, as I have tried to show above, Bacon did not give any role to pure mathematics in natural philosophy.

[10] For the quantitative approach in Baconian natural history, see Rees (1985), Jalobeanu (2016) and Pastorino (2011a, 2011b). For Bacon's conception of natural history as a foundation of true natural philosophy, see Manzo (2009) and Jalobeanu (2015b).

[11] For a natural history of the heavens in Bacon, see Jalobeanu (2015a).

to actuate the axioms regarding the motions of celestial bodies into practice, such as designing a calendar or predicting the next lunar eclipse.[12] Since mechanics and magic are the operative parts of natural philosophy, we cannot also think that Bacon did not give any role to mathematics for the operative part of natural philosophy in the *Advancement of Learning*. As you remember, both in the *Advancement of Learning* and *De Augmentis Scientiarum*, Bacon says that mixed mathematics has as its subject some axioms and parts of natural philosophy, but he did not say some axioms of metaphysics. Instead, Bacon said both in the *Advancement of Learning* and *De Augmentis Scientiarum* 'parts of natural philosophy.' Therefore, we must surmise that Bacon gave a role to mathematics in every part of natural philosophy both in the *Advancement of Learning* and *De Augmentis Scientiarum*, and this role was an auxiliary role to his inductive experimental method.[13]

3. Conclusion

In this paper, I have argued that Bacon's attitude towards the role of mathematics in natural philosophy did not change between his *Advancement of Learning* (1605) and *De Augmentis Scientiarum* (1623); and related to this claim, I have also argued that Bacon gave an auxiliary role to mathematics both in the *Advancement of Learning* and *De Augmentis Scientiarum*.

Rees argues that, alongside metaphysics, Bacon extended the role of mathematics to physics, metaphysics, mechanics and magic in *De Augmentis Scientiarum*. From this argument, we can conclude that Bacon gave a narrower role to mathematics in the *Advancement of Learning*. For Rees, Bacon placed mathematics as an adjunct of metaphysics in the *Advancement of Learning*. What we know about what Bacon offered for the relation between mathematics and metaphysics in the *Advancement of Learning* is that he placed mathematics as a branch of metaphysics, and placing mathematics as a branch of metaphysics was not something about the role which was given to mathematics, but rather a classification of mathematics as a part of metaphysics, since its object (quantity determined) is one of the essential forms of things.

Bacon gave an auxiliary role to mathematics not only in *De Augmentis Scientiarum* but also in the *Advancement of Learning*, and placing mathematics as a branch of metaphysics both in the *Advancement of Learning* and *De Augmentis Scientiarum* was a classification of mathematical sciences (that is, mixed mathematics) in metaphysics because the object of mixed mathematics (quantity determined) is one of the essential forms of things.

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Table 1

	Pure Mathematics	Mixed Mathematics
Its object	Quantity indefinite	Quantity determined (or proportionable)
Formal status	It is not a form	It is one of the essential forms
Its relation with matter	Fully separated from matter	The most abstracted form from matter
Its relation with natural philosophy	(–)	A part of natural philosophy (A branch of metaphysics)
Its role in natural philosophy	(–)	Auxiliary
Sorts	Geometry, Arithmetic	Perspective, Harmony, Astronomy, Cosmography, Architecture, Machinery, etc.

[12] For the application of geometry to develop instruments such as devices for the art of warfare, see Bennett (2002 and 2011). For a discussion in the sixteenth century on whether astronomical instruments could represent the cosmos, see Mosley (2006). Thomas Tenison (1636-1705) informs us in his *Baconiana* that Bacon also made a mechanical device representing the planetary motions; see Tenison (1679, p. 17-18). I thank Sophie Weeks for letting me know about this invention of Bacon. On the status of the mechanical arts in the sixteenth century, see Heikki (1999). On mathematical practitioners and their role in the adoption of the language of mathematics in natural philosophy, see Cormack (2016).

[13] For the Baconian inductive method, see Hesse (1968), Horton (1973), Malherbe (1996), Pérez-Ramos (1988), Serjeantson (2014) and Vickers (1992). Please see table 1, which summarizes the arguments made so far.

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