THE INTERRELATIONSHIP BETWEEN THE MATHEMATIZATION OF SCIENCE AND THE IDEA OF UNIVERSAL FORMAL LANGUAGE OF SCIENCE

Nijole Aukstuolyte, PhD
Mykolas Romeris University, Lithuania

Abstract
The paper analyses the development of theoretical thought producing the idea of the language of mathematics as a universal formal scientific language and consolidating it in the Early Modern epistemological analysis of language. The mathematical reflection of the world as well as the critical approach to the natural language with regard to its suitability for the purposes of cognition highlighted the cognitive significance of signs and the way of their application. That directed the philosophers’ efforts towards the search for the proper language of science. The paper reveals how, reflecting mathematics not only as an instrument of knowledge acquisition and its organization model, but also as language, the mastering of which determines the possibilities of the study of nature, formalistic investigations of language raising the problem of the epistemological possibilities of the language of science, becomes dominating in the Modern philosophy.

Keywords: Epistemological analysis, formalistic investigations on language, language of mathematics, universal language

Introduction
The search for precise and uniform structure of knowledge, which started with Aristotle’s epistemological research, turned the philosophers’ attention to the investigation of the formal linguistic aspects of knowledge. Of no less importance is ancient mathematics which considered number as a key to disclose the secrets of the Universe and as a tool to cognize the unity of nature. Mathematical relations were used to explain the relations between the phenomena of the world and to discover its formal structure. Acknowledging that the unity of different objects is expressed in numbers, the mind is liberated from the unnecessary analysis of particular material peculiarities and thus it can focus on the structures encompassing the objects
of different content and quality. The number gives the possibility to move from undefined qualitative characteristics to quantitative explicitness, which, in its turn, is related to language. What cannot be defined cannot be named, since, according to Plato, ‘one should never describe them as ‘being’ seeing that they change even while one is mentioning them’. (Plato, 1995, p. 94). Numbers, however, when defined and thus identified reveal the nature of things perceived sensually.

Aristotle’s idea of the importance of form in cognition, association of knowledge with relevant linguistic expression as well as distinguishing of formal thinking operations gave a start for the analysis of formal aspects of language. Aristotle’s theory of syllogism, request for definiteness of meanings which testify his utmost concern towards the linguistic structure of knowledge and its exactness provided the possibility to analyze language as a formal system of knowledge. Being aware of the formal structure of knowledge, the antique philosophers gave impetus for its structural studies, however, they were mostly concerned with the possibilities of language to define the real nature of things. The Antique philosophical reflection discusses the relationship between being, knowing and language and seeks for true knowing, conveyed as ‘true things’, in other words, the names of the essence (Aukstuolyte, 2005).

The dispute triggered in the medieval philosophy around the universals enhanced the concern for the study of formal aspects of language. In the Middle Ages the analysis of the form of knowledge started by Antique thinkers turned into the search of formal rightness of thoughts expressed by signs and the study of adequacy of thoughts to things typical to the ancient thinkers was changed into the study of names. The expressed role of denotation and signs enhanced the focus of attention on formal studies of knowledge and determined the formalistic approach to language.

The aim of the paper is to discuss the factors which led the Early Modern philosophy to the idea of universal language of science and its realization and to show the interrelations of the mathematical language as the model of scientific language with the emerging domination of the trend of formalistic language study.

I.

In the epoch of Renaissance the antique tradition of mathematics revived in the works by Nicholas of Cusa and in the treatises on natural sciences by Leonardo da Vinci and Galileo Galilei became the basis for the unity of nature and method of its study. At the time of specialization of sciences and their rapid development the mathematics is recognized as the criterion of science. In addition, according to Leonardo da Vinci, the real role of mathematics is distinguished in the content of other sciences,
especially in mechanics with its efficient mathematical apparatus (Leonardo da Vinci, 1955). The mathematical algorithm in separating form from content provided the possibility to analyze it as a formal scheme of knowledge. For example, geometrical figures, such as angle or triangle or any other figure, possess their own individual features distinguishing them from other analogous figures and those typical to all figures of that sort. The latter are identified as the essence of the figure which is not the object of sensual perception. Therefore, ‘angle’ or ‘triangle’, etc., are only mentally perceived general principles symbolizing all possible diversity of their expression. Therefore, mathematical structures are recognized as capable of being idealized equivalents of real objects applicable to reveal the unity of different spheres of the world. The emphasis on the mathematical symbolic function reduced the distinction between the ideal and the real physical worlds and enabled mathematics as the theory of general principles to be applied for cognition of concrete objects. That revealed the significance of mathematical cognition in the general context of science and created preconditions to see that mathematics incorporates things making it an instrument of cognition without which human mind would not be able to perform its cognitive functions. According to Nicholas of Cusa, ‘everything that is not related to a set or magnitude is not subject to understanding or representing or imagining, naturally, it is not subject to cognition’ (Nicholas of Cusa, 1980, p. 161).

The philosophical reflection of mathematics leads to the idea that due to its symbolic nature mathematics always deals with general principles, however, these principles can be readily applied for real objects. Mathematical constructions and symbols can be used to explain the character of natural phenomena and their relations. In solving the issues of astronomy and physics geometrically Galileo Galilei substantiates the power of mathematics to express all the diversity of nature by means of the same universal laws expressed by unified formulae. By means of these formulae due to certain rules mental structures are constructed expressed by the language of mathematics relating them to real objects. Galileo interprets mathematics as the ‘language of nature’ which must be understood in order to be able to raise questions to nature and interpret its answers, i.e. as the universal method of the study of physical world. According to him, ‘the laws of Nature <...> are written in the language of mathematics; its symbols are triangles, circles and other geometrical figures, without whose help it is impossible to comprehend a single word’ (Galileo, 1987, p. 41). Mathematics does not allow us to contrive, to make exceptions, to rely on authorities or verbosity. The proof must be concise because mathematical strictness requires conciseness.
Galileo’s general idea that the issues of natural sciences should be solved by means of mathematical procedures is based on a very simple reason: there simply is no other way to find the truth. Without mastering mathematical procedures the nature is not accessible for the researcher. According Galileo, ‘mistakes lie not in abstractness, not in concreteness, not in physics or geometry, but, rather, in the one who calculates and who cannot calculate correctly’ (Galileo, 1964, p. 307). The capacity of mathematics to express diversity of nature by unified formulae makes it possible to recognize it as a unified and precise instrument of the investigation of nature, and to equate mastering of mathematical algorithm to mastering of nature, i.e. to base the possibilities of nature investigation on it. Such approach directs the researchers’ attention to the application possibilities of mathematical standards and methods in explaining the phenomena of material world and transforms mathematics into universal method of sciences.

Similarly, attention to the language of mathematics as the model of scientific language was stimulated by doubts about the relevance of the natural language to perform the function of cognition. In New Organon Francis Bacon sought to identify those doubts by saying that ‘[people] think that their reason governs words; but it is also true that words have a power of their own that reacts back onto the intellect <...> Because words are usually adapted to the abilities of the vulgar, they follow the lines of division that are most obvious to the vulgar intellect. When a language-drawn line is one that a sharper thinker or more careful observer would want to relocate so that it suited the true divisions of nature, words stand in the way of the change” (Bacon 12). Therefore, scientific discussions turn into disputes on words and signs. According to the philosopher, in order to avoid ambiguity, the discussion should start with signs as mathematicians do. Bacon clearly declares his discontent with ordinary language which hinders solution of cognition problems. According to him, ‘magic power of the word to confuse our intellect’ requires some antidote to overcome inaccuracies and shortcomings of the natural languages. He proposes reformation of language, however, without seeking to transform it into logical or mathematical structure.

Bacon’s criticism of the natural language did not remain ‘voice in the wilderness’. Thomas Hobbes and John Locke were also involved in epistemological research in disappointment with the state of natural language. It is recognized as an imperfect tool of cognition, because the speaker chooses words and freely uses them without clear ideas, if any, and tends to identify words with things. This way there is a possibility for abuse. Therefore, in order to avoid the power of words over mind, the question of
language being capable of properly performing the cognitive function should be raised.

The perceived power of words led to the search of appropriate principles of organization of linguistic expressions, to the analysis of the denotation power of words, i.e. to start formal study of language. The requirements for proper usage of language raised by Bacon, Hobbes and Locke demonstrate the recognition of active role of language. The conception of language established in philosophy of empiricism as the instrument of cognition eliminated any doubt about the importance of language in science; however, it expressed doubts about the relevance of natural language to perform that function.

The disappointment with natural language inspired the idea of distinguishing the words for everyday usage and for the area of philosophy, i.e. science. 'By the philosophical use of words, I mean such a use of them as may serve to convey the precise notions of things, and to express in general propositions certain and undoubted truths, which the mind may rest upon and be satisfied with in its search after true knowledge' (Locke, 465). Much higher requirements for the language of philosophy are set which implied the idea of a universal language of science. Bacon imagined the language of science as a system comprised of purely conventional elements representing not words, but, rather, things and concepts. Proposing the construction of an artificial language he even defined its structure, i.e. the model of rules expressing common features of grammars of different languages. It could be used by people speaking any language and also serve as an antidote for so-called 'tongue confusions'. Critical approach to the potential of ordinary language to clearly express the content of concepts remained alive until the middle of the 20th century when Wittgenstein again brought back the words of science into the everyday usage.

The nominalists noticed conventionality of the link of words and ideas denoted by them. Empirical cognition of the world presupposes rather different ideas of the same substance, because not the same features of objects are cognized. In this way different and undefined meanings of words are formed, and different meanings with the same sounds link different ideas. Since words are the names given to denote concepts and they are identified conventionally, there occurs an idea that conventionality of identification determines the conventionality of knowledge content lying in the sentences. This presupposes an erroneous idea that relations between concepts can become dependent on linguistic agreements and scientific truths are derived following the agreement on the meanings of words, which is undoubtedly unaccepted in science. Undefined and incorrect expression of ideas by words as well as their inconsistent usage is similar to the situation when one and still another combination are denoted by the same figures. It is like when
number 3 denotes three but sometimes four and sometimes eight units. Such behavior with numbers is unimaginable in arithmetic and commerce; however, undefined usage of signs in philosophical disputes is a reality blocking the search for knowledge (Locke, 482). Words being intermediaries between our mind and truth, which is to be perceived by mind, frequently darken our insight and fool our mind by their disorder and vagueness.

The empirical conception of cognition which considers sensual experience as a source of knowledge saw words as sensual signs of ideas, whose reliability determines certainty and truths of knowledge. The philosophers, well aware of the importance of language for knowledge and in knowledge, but with discontent towards everyday language, which confuses mind by its vagueness and uncertainty, focused their attention on the instrumental function of language. The empiricists accentuated the importance of signs and denotation by substituting the relation of word and thought by the relation of sign and its meaning. They stimulated analysis of the formal aspect of language and formulation of correct language usage rules by means of definitions.

Definitions by their precision eliminate ambiguities in words, fix the concept defined and the context of its usage. They allow division of the concept into constituent parts or formation of a more general concept out of concrete ones. The object of definition is considered to be not things or their nature, but, rather, terms. The best way to define is to enumerate simple ideas; however, it is not possible to define all terms. There exists a set of undefined terms called simple ideas which is used to define terms denoting intricate ideas. This idea was later developed by Gottfried Wilhelm Leibniz in his Characteristica Universalis, by Bertrand Russell and Ludwig Wittgenstein in the conception of logical atomism. The theory of logical definitions started by Hobbes was extended by Locke. Their theory is designed to determine the meanings of names, at the same time highlighted the role of definition as the model of deductive reasoning.

By knowing the exact meanings it is possible to reveal the correspondence or non-correspondence of ideas to the things they reflect. However, people tend to start with the wrong point, i.e., they try to learn the words perfectly, and form the concepts rather superficially, therefore, even though speaking accurate language and observing grammatical rules they tend to judge about things absolutely incorrectly. Locke, as a real empiricist, maintains that sometimes meanings can be better conveyed by pictures describing things or prints than a long definition of names (Locke, 513-514). In this context the comparison of Locke’s idea with Ludwig Wittgenstein’s much later idea of language as a picture of reality is quite interesting. That idea occurred to Wittgenstein after he saw a picture in a newspaper describing possible consequences of a car accident. The picture replaces the
story. Wittgenstein concluded that the same can be applied to language saying that a sentence performs the function of a picture, i.e. that there is a similar adequacy between parts of a sentence and combinations of world elements. In *Tractatus* this led the author to the study of the sentence structure, possibilities of comparison of language and the world structure, in searching the connection between signs on paper and situations in the world. This is told by Georg Henrik von Wright, Wittgenstein’s biographer and researcher of his works (Wright, 1955). So, Locke and Wittgenstein are two authors of different times related by their critical approach to the natural language as inaccurate system of signs and by the search for an appropriate language of science. Great attention to language paid by Locke encouraged other researchers to regard the section About words’ from ‘An Essay Concerning Human Understanding’ as the first modern research work specially dedicated to language philosophy (Kretzman, 1976).

But the idea of universal language of science belong to Rene Descartes. He sees mathematics as a universal language of nature and is of the opinion that a unified formalism has to be created based on mathematics as on an example which could become not only the basis for the unity of knowledge, but also a tool for theoretical cognition providing the ways for the solution of problems. Continuing the development of mathematical study of nature he transforms the old conception of mathematics by replacing it by the program of universal, or general, mathematics as by formal instrument able to scientifically construct the world. Descartes admits that he means not the usual mathematics, but, rather, quite another science the role of which should be the truth and ‘which is more important to any knowledge provided to us, people, because it is the source of all other sciences’ (Descartes, 1978, p. 32).

General mathematics is based on the idea of one form of knowledge which is not related to number, spatial form or to something else definitely, but it is related to everything determined by measure and order. According to Rene Descartes, all areas of knowledge can be expressed by unified formalism by abstracting from the specificity of the content, i.e. from the area of matter they study. The formality of universal or general mathematics can enable abstraction from the specificity of content, and reveal the commonness of the world of beings by means of algebraic signs. It could represent the general form of knowledge and give the possibility to ‘calculate’ any reality. According to the philosopher, it is only from the first sight that arithmetic and geometry, statics and mechanics, astronomy and music seem to deal with different objects; actually, those are different aspects and manifestations of the same rational form.

Descartes based the idea of a universal language of science on the assumption that language is to remain the same, irrespective of what it
communicates. The most important thing is its simplicity and clarity. It could and should become an instrument to scientifically construct the world. The author formulates simple and accurate rules which, if properly applied, are supposed to protect mind from considering wrong as right and help mind to cognize everything that is possible to be cognized. In other words, he seeks to create a universal research method by means of which it is possible to study all objects of cognition, and identifies it as a universal language of science capable of expressing the structure of the world. By treating the language of mathematics as the basis for the unity of knowledge and the instrument of theoretical cognition, he acknowledges it as a potential standard of science which gives the possibility to express the content and structure of different thoughts by a limited number of signs. In fact, Descartes failed to take practical actions to realize that idea, he did not develop the project of the universal language, however, he proposed the principle of linguistic unity in science. That idea became a starting point for numerous future projects of the universal language of science.

Many different projects were started, but it was Gottfried Wilhelm Leibniz who sparked the methodological sense of Descartes’ idea, contrary to other authors of that time (Dalgarno, Wilkins) who emphasized its technical side. Unlike the latter thinkers, Leibniz saw the artificial universal language not as the means of arrangement of concepts, but, rather, as a necessary tool of theoretical knowledge. In 1666 at his twenty years of age he wrote the work on combinatorics where he publicized the idea to create an ‘alphabet of human thoughts’ from which it could be possible to deductively obtain new knowledge by using certain rules. The aim of his work was clearly and unambiguously described in his letter to the Duke of Hanover: ‘to develop the art of revelation which helps to find not the solutions of individual problems, but, rather, solution methods, since one single method covers a multitude of solutions’ (Leibniz, 1984, p. 491). Unlike Descartes, he thought that practical realization of an artificial universal language as the cognition method was possible.

Leibniz developed the system of universal artificial language on the example of mathematics by calling it ‘Characteristica Universalis’. Even though his project underwent changes in the course of development of Leibniz’ thought, it was always understood as a certain mathematical procedure more general than the methods of mathematics of that time. That binary system is composed of calculation and syntax. Calculation is a system of simple primary signs (characters) expressing simple concepts and is understood as ‘the alphabet of human knowledge’. Syntax is a set of operation rules of those signs while reducing complicated concepts to simple ones and joining simple concepts into complicated ones. In that system not the signs as such are of importance to the author, but, rather, their relation
with the whole system of signs. On the other hand, it does not mean that Leibniz selected symbols at random. He emphasized once and again the importance of selecting symbolism: signs should be ‘convenient for discovery’, i.e. designed to concisely and adequately express the idea, but not only represent the object being signified. And this is not a theoretical statement. The simplicity and convenience of his symbolism in science is approved by its relevance for the operations of differentiation and integration.

By means of the artificial language the author sought to express the structure and diversity of knowledge not by the choice of signs, but by the relation of elements and their interrelation. The author was interested not so much in signs (though they are not accidental for Leibniz), but their interdependence and order. The author of ‘Characteristica Universalis’ highlighted a very significant thing: the relation lying in the relationship of signs is not conventional. Even though the signs are selected freely, their usage and their relations imply what cannot be selected freely. Their relation is the basis for truth (Leibniz, 1984). Due to this reason ‘Characteristica Universalis’ is understood as an instrument of cognition, the method of finding and determining the truth embodying the correct way of reasoning. The artificial language is understood as a unified algorithm of science due to which the content of thinking is formalized. This language allows us to see whether or not one sequence follows from others and reveals how it can be divided into simpler constituent parts, on which both its correctness and meaning are based (Ishiguro, 1972). This is the way not only how the elements of knowledge are obtained, but also by means of syntax it can be determined which of them are nonsense, and which are correct. The interrelation of thoughts becomes transparent and, according to Leibnitz, the truths themselves prove one another (Leibniz, 1984).

Leibniz drew the philosophers’ attention to the problem of limits and possibilities of formalizing the content of thinking and the principles of its functioning, which has so far remained open for new ideas and solutions. The author’s aim is to create a language by means of which it could be possible to make correct judgment without thinking of the interpretation of signs, only using the rules of junction and changing of signs, i.e. to formalize the cognition process in a way that it would not be important whether the signs express sensual experience or insight of mind, but, rather, whether they do it in a simple and clear form. Mathematics was best suited for that purpose, because it gave the possibility to think by means of calculation and, in the case of disagreement, to find mistakes by calculation. Actually, a mistake made by mind using arithmetical and algebraic signs is also a mistake of calculation. The content of knowledge is made transparent when mathematizing it. Leibniz maintains that absolutely everything can be
expressed in the language of mathematics. For him, number is kind of a
metaphysical figure revealing the nature of things.

Conclusion

The trend of mathematizing natural sciences resulted in the turn of
mathematics into the universal method of sciences. Formalization of
mathematics highlighted the significance of the form of knowledge and led
to the assumption that the same formalism can be applied in relating different
cognitive content. Such sequence of theoretical thought reinforced by the
criticism of cognitive possibilities of a natural language produced the idea of
an artificial language. Its practical realization in the project by Gottfried
Wilhelm Leibniz Characteristica Universalis illustrates how the model of
the language of science is developed on the example of the mathematical
language.

Leibniz was the first to develop artificial language of science which,
in its turn, stimulated the formalistic investigations of the language which
further developed into the elaborate theories of linguistic determination of
cognition. The technique of structural investigation is being developed, at the
same time with restriction to the treatment of the instrumental role of
language in science. The language of science is seen as a formal system able
to facilitate correct reasoning without thinking about interpretation of signs,
but only operating them properly. All this raises the question for further
philosophical research: to what extent formalization can be independent and
inclusive expression of scientific thought, and formal studies can be regarded
as the best way of addressing epistemological problems of the language of
science.

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