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The didactics of mathematics within the classification of modern sciences from the perspective of categorical closure

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ABSTRACT

An important question is to know why the didactics of mathematics (DM) goes from being only teaching techniques to consolidate as a science and also to locate what kind of science it is. The objective of this article is, through a modern classification of sciences, such as the theory of categorial closure, to locate the DM. Likewise, a very brief summary of the theory of categorial closure is made, and it is argued why DM belongs to the human sciences and why it is not a technique.

Keywords: didactics of mathematics, theory of categorial closure, human science, classification of sciences

INTRODUCTION

If a person were to ask the general public, is mathematics a science, most probably most of them would answer yes, because it might even seem ridiculous to think otherwise. In fact, the year 2022 was considered the year of basic sciences worldwide, where mathematics was part of it.

On the other hand, when talking about didactics of mathematics (DM) and its scientificity the picture does not seem so clear, because even several teachers do not consider didactics as a science. Abreu et al. (2017) conducted a study, applied in the faculty of administrative and economic sciences (FACAE) of the Technical University of Northern Ecuador, where they found that 27.8% of FACAE teachers do not recognize didactics as a science, 8.8% state that it is part of pedagogy, 15.2% say that it does not have an object of study while 13.9% do not identify it.

Many teachers and researchers still consider that didactics is a matter of experience. In this regard, Niccoló Tommaseo (1802-1874) (as cited in D'Amore, 2011) stated, "*The rules of didactics; they are not taught by method books, otherwise the heart, with the example, with experience*" (p. 34). It is incredible that, in spite of having so much time, and in spite of the progress in didactics, this perception is still held. Gallastegui (2002) mentions that in the community of those engaged in mathematical research (university professors), it is usual to maintain a traditional position on theoretical and practical pedagogical issues. In addition to didactic questions, disdaining them, perhaps considering that such studies and occupations constitute a second or third category field, in which it is very easy to decide which are the most appropriate options at any given time, and in which anyone who has practiced as a teacher for a few years is as authorized as anyone else to issue a valid opinion.

An intriguing question arises in relation to DM: can this discipline be considered a science? To address this question adequately, it is essential to turn to philosophy and use the contemporary classifications that exist in this field. In this article, we will delve into the theoretical perspective of categorial closure, a theory that will be developed in more detail in the next sections. Through this perspective, we will seek to precisely define the position of DM within this philosophical and epistemological context.

The theory of categorial closure will play a central role in our exploration, as it will allow us to shed light on the nature of DM and its place in the academic landscape.

THE THEORY OF CATEGORIAL CLOSURE

Before beginning, it seems pertinent to explain why it was chosen to use the perspective of categorial closure for the classification of the sciences. It must be understood that the extensive work of the philosopher Bueno (1972), as Alvargonzález (2021) states, has already earned a relevant position, where his work represents an attempt to propose a philosophical system on a par with the knowledge of the *present.*

This idea of categorial closure is a concept proposed by an academic philosopher in Spanish, and there is no equal or similar concept in any other modern language. This idea has been extensively developed in a treatise of five volumes with over 1,400 pages and has given rise to 14 monographic doctoral theses as cited in Alvargonzález (2021, p. 77: Álvarez, 2002; Alvargonzález, 1989; Baños, 1993; Barbado, 2015; Fernández, 1980, 1995; Fernández-Treseguerres, 1993; Fuentes, 1985; Hidalgo, 1990; Huerga, 1997; Iglesias, 1992; Lafuente, 1973; López, 1983; Madrid, 2009). The phrase "categorial closure" generates over twenty thousand pages and 1,200 videos on Google, with more than one thousand results on Google Scholar (Alvargonzález, 2021). Therefore, once this has been introduced, we can proceed with the explanation of the theory.

The classification of sciences is a task of the philosophy of science, since the proliferation of modern sciences after the scientific and technological revolution. Alvargonzález (2022), inspired by Bueno (1972), proposes his theory of categorial closure and starts with two principles. The first is that philosophy is not a science; the sciences are knowledge of the first order, disciplines constructed directly with objects and material operations carried out with objects. Philosophy, however, is a second-order knowledge that requires the prior existence of first-order knowledge such as techniques, sciences, technologies, ethical and political knowledge, etc.

To present the second principle, we consider it pertinent to review the meaning of categorial closure. Bueno explains that it should be understood as closure, in a similar way as it is understood in mathematics, as when talking about the closure of a field. That is, two elements are considered, and under an operation, a third term belonging to the field is obtained. An example is to take 2 and 3 from the field of natural numbers, apply the sum, and obtain 5, which still belongs to the natural numbers, thus maintaining the relations and the belonging to the field. The categorial part comes from the idea of category, which refers to the fundamental idea introduced by Aristotle that underlines the character of the universe as divided into domains somewhat irreducible to each other (fgbuenotv, 2010, 0m31s). So, by applying Aristotle's categories, the idea of closure is meant, which is that these categories are not prior to the process of internal operative closure but result from the operative process itself. So, we would say that there are as many categories as there are sciences.

This is the opposite of what was presented by Nicolas Bonnetti in the 16th century, where Bonetti stated that there were as many sciences as categories, and taught that there was a need to recognize thirteen different sciences, the science of the entity, the science of the Infinite, the science of the Finite and the ten sciences corresponding to each of the Aristotelian categories (Alvargonzález, 2021; Bueno, 1972).

This definition aligns with what Alvargonzález (2022) presents in the following principle: Although a particular science can be comprehended as a complex system of theorems, there is no "system of sciences" since a set of systems is not necessarily a system, just as a group of political states is not a state and a set of circles is not a circle. The importance of this principle lies in the fact that since there is no system of sciences, there is no single scientific system in which the theorems of all sciences are coordinated by the same principles, so we cannot speak of "science" in the singular, but rather we can speak of sciences and how these are defined by the categorial closure. All this is of utmost importance, because when people think of science, they imagine a single science, that is, they describe certain parameters that they consider it must fulfill, and when a given science does not fit their own description of science, they discard it without considering that the sciences are independent of each other, and therefore their principles will be independent of each other.

In the history of philosophy, it has been recurrent to pose the classification of sciences as an ontological problem. This assumes that the sciences describe the world or reality as if it were a map of it, thus reducing the classification to the division of reality into parts. The idea of categorial closure denies the previous idea because it refuses to accept that this is a description of reality, a mere theoretical elaboration, or a map of the world. The sciences do not have a single object of study (nature, life, culture, etc.) but a complex field made up of a multitude of objects (Alvargonzález, 2019).

Finally, Bueno mentions that science is an intervention, or an incorporation of the world itself into reality, by means of apparatuses, by means of one's own interventions on the world. Therefore, for Bueno, the sciences are not merely speculative with respect to the world, or to knowledge, but involve an organizational activity on the world in relatively immanent and closed circles in which truth can be produced (fgbuenotv, 2010, 3m59s).

Classification of the Sciences

The classification proposed by Bueno and later by Alvargonzález (2013) is complementary, it is not new, in fact, it had already been presented previously. However, the way in which it is justified is innovative. This classification is presented below.

1. In formal sciences such as logic and mathematics, they work with typographic objects, which are self-referential signs.
2. In the so-called natural sciences (physics, chemistry, biology, etc.), scientists operate with objects that are not signs, such as bodies in motion, substances, organisms, etc. Although signs can be found, they are used to refer to objects. Therefore, unlike formal sciences, they are not self-referential. This is why we can say that the objects used in these sciences are non-operational objects.
3. In the human and ethological sciences (linguistics, cultural anthropology, sociology, psychology, ethology, etc.), we can say that we operate with objects and operations. The objects are inert, but we also operate on the very operations of the subject subjects (native speakers, social agents, animals, etc.). When the subjects of which we speak are animals, we then speak of fields like animal psychology, ethology, etc. But when the subjects are humans, we are in the field of human sciences. Both ethological and human sciences handle two levels of operations: the operations of the scientist and the operations of the subjects being studied.
4. In the historical sciences, we have to work with remnants, monuments, ruins, and documents. Since our subject is deceased, we must establish operations through deduction obtained from these objects.

The Human Sciences From the Point of View of Categorial Closure

For many years, the human sciences have been wrongly called "soft" sciences, while the natural and mathematical sciences were known as "hard" sciences, those that work with data and accuracy. Unfortunately, this idea seems to have originated at school, where one begins at a very young age to denigrate sciences that are not hard, and is accentuated at university, where in some science faculties there are still professors who express their disdain or contempt for these sciences.

Gil and Paz (2009) suggest that there is a separatist model between hard and soft sciences. This affects crucial stages such as adolescence, since it promotes the idea that only a privileged group with a supposedly superior intelligence can choose to pursue scientific studies, with highly paid careers, while others have to turn to humanistic careers because they have been taught since childhood that they are not capable with the exact sciences (mathematics, physics, chemistry, among others) and should go "somewhere else", different from the previous ones.

One might suppose that what was stated in the previous paragraph is already in the past, however, this idea is still valid, even in scientific research. People that we consider men of science still consider that there are soft sciences. But let's start to unravel all this, first by explaining why they were called soft sciences. Mangione (2015) explains that this term is erroneous and unfair. He adds that this term is based on an outdated and old view of what positivism was, where that which was a matter of opinion was soft and that which did not admit opinion was hard. This is far from true, not because there are no aspects of scientific work that are opinionated or not. It is because in reality, what is done when research is carried out starts from constructs, opinions, abstractions, previous hypotheses, laws; but all of them are objectified.

With all of this explained, it seems relevant to continue and examine the human sciences as categorized by the categorial closure and thus appreciate the complexity they present.

As mentioned in the section on science classification, the human and ethological sciences operate on a double plane–the actions of the subjects and those of the scientists who study them. Alvargonzález (2023a, 2023b) explains that the fact that the operations of the subjects are in the field hinders the construction of identities, truths, theorems, but above all principles. It is worth mentioning that it is not that there are no principles, on the contrary, there are too many principles, this is due to the fact that in general different schools propose different principles, as we can see in psychology, where we find behaviorism, cognitivism, etc., and different principles are proposed according to these. Therefore, this is what makes the unification of principles difficult.

For the above reasons, there is a "phenomenal" closure, since it only achieves a partial ordering of certain phenomena (Bueno, 1972). In these sciences, experimentation always implies acting on animal behavior and human praxis, which means that there is no clear solution of continuity between scientific activity and the techniques of control over the subjects: techniques of domestication and animal learning, techniques of colonial, social, or economic control, psychological techniques, etc. As Alvargonzález (2013, 2019) has shown, in these sciences, although certain phenomenal theorems of local scope can be constructed, there is no unanimity around the principles and, therefore, the coordination and systematization of theorems in a unified field is not achieved so that it always remains open to an irresolvable discussion: one can speak, then, of a closure that is more intentional than effective.

All this reinforces the idea that there is no "science" in which its principles or methods determine all sciences, because, as has been explained, each science will have its own particularities and its own type of closure.

THE PLACE OF DIDACTICS OF MATHEMATICS

As we have explained before, we will use the classification of sciences proposed by Bueno (1972) to locate the DM among the human sciences. However, several authors have previously stated that the DM is a science and even classify it as a social science. In this way, we will not be doing anything new in this sense, but how it is argued, why it is a science, is what we try to innovate. Next, we will briefly review the arguments of other authors about why DM is a science.

One of the most recent works is that of Situngkir and Dewi (2022), although it is worth making a clarification here, they use the term mathematics education, while in this work the term DM is used. In that sense, D'Amore (2011) explains that there is similarity in the terms and when used, DM seems to have a subtle type of meaning that includes another property. However, for the purpose of this article, they will be used as synonyms, since the discussion of the similarities and differences of these terms goes beyond the purpose of this work.

Situngkir and Dewi (2022) base the vision of DM through philosophy, explaining that the source of philosophy is man, reason, and the human heart. Mathematics is given as an example, and it is mentioned that this discipline is a science about reasoning, patterns, and relationships. Mathematics supports development because people want a pattern that is organized, easy to understand, and made so that anyone who reads and studies it can easily understand it. This definition of mathematics and its importance for students seems pertinent, but we would like to add what Brousseau (2000) states: "mathematics constitutes the field in which the child can begin rationality the earliest, in which he can forge his reason within the framework of autonomous and social relationships" (p. 6).

Situngkir and Dewi (2022) consider DM as a mathematics lesson that helps students develop logical thinking and mathematical knowledge. Additionally, they base it on the philosophy of mathematics and state, "Philosophy plays a role in creating mathematics learning that enables students to develop their logical thinking and mathematical knowledge. Philosophy and science are united and have a complementary relationship" (p. 4). Situngkir and Dewi (2022) add that "Philosophy and science are interrelated because everything is a human activity. The relationship between the two is similar to philosophy as the mother of science, while science is the daughter of philosophy" (p. 4). These authors mention characteristics of philosophy and discuss the

relationship between mathematics and science. At the end of the article, they conclude by saying that the philosophy of mathematics education and scientific education goes hand in hand to discuss the phenomenon of education and truth in education.

Although we share many of the points made in this article, in some, we have a certain reluctance to accept them. The first incompatibility that we find is when they mention that the DM is a math lesson and defining it this way seems to detract from the scientific nature of this term. It seems to reduce it only to a subset or tool of mathematics. It must be remembered that DM is a completely different science, where the objects of study are different, its operations are different, and its nature is different. This means that, when comparing it with mathematical sciences, which belong to the formal sciences, its scientificity may pale. However, DM must be classified with its peers, that is, with the human sciences.

On the other hand, we agree that it is necessary to involve philosophy to determine whether mathematics teaching is a science. We propose that it is necessary for the philosophy of science to determine it, and even more, this issue must be determined by a recent and established theory, while here they are based on the philosophy of mathematics to give a vision of the DM as a science. Although we share the idea that philosophy and science are interrelated, we differ in the claim that philosophy is the mother of science. In this regard, Bueno (1995) tells us that philosophy, in its strict sense, is not "the mother of the sciences", a mother who, once her daughters grow up, can consider herself retired after thanking her for the services provided. On the contrary, philosophy presupposes a state of science and techniques sufficiently mature so that it can begin to constitute itself as a defined discipline. For this reason, the ideas that philosophy deals with, ideas that arise precisely from the confrontation of the most diverse technical, political, or scientific concepts, starting from a certain level of development, are more abundant as that development occurs. That is, let us remember that philosophy by itself cannot produce identities like science, that is why philosophy is a second-order knowledge, which requires the assumption of a mature state of sciences and techniques. The role of philosophy in science is criticism, which achieves the refinement of techniques and sciences through it.

In order to consider science didactics as a science, it is necessary to mention one of the fundamental characters, and that is Brousseau (2002) with his theory of didactical situations in mathematics. Artigue et al. (2011, p. 2383) (as cited in Gascón, 2013) explain it, as follows: Nowadays, the notion of "phenomenon" does not have a central function in many approaches to mathematics teaching. However, it played a crucial role in the emergence of the theory of didactic situations and its vision of didactics as a scientific discipline. In the first developments of this approach in the 1980s, and through several different formulations, Brousseau (1997) defined mathematics didactics as the science whose essential objective is the knowledge of didactic phenomena, that is, the phenomena that appear in the teaching and learning process. Or, more generally, the dissemination of mathematical knowledge in social institutions (including schools). Therefore, didactic phenomena must be considered both as a construction and as an object of study of didactics, in the same way that physics studies the specific construction "physical phenomena", or sociology studies and also defines social phenomena, etc.–including all historical controversies about the delimitation of phenomena in nature and social sciences. Once the definition of DM has been provided, it can be argued why DM belongs to the human sciences.

To begin this discussion, Alvargonzález (2020) tells us that the constitution of a scientific field is a historical process that can last centuries and in which many researchers intervene. Although all sciences have been constructed by men, this is not an impediment to claiming the objective character of scientific fields understood as an anthropic systems.

For this reason, it is important to mention that it is a fact that DM is a young science, it has not been created for so many years and, without a doubt, there is still a need to continue working on it, but that is not an obstacle to considering it. as science.

We consider that DM is classified in the human sciences, since among the terms with which it operates are people, human subjects with certain characteristics (of different ages, with different motivations and expectations, made up of often contrasting cultures, etc.) , so when it comes to establishing relationships between them, we will never be able to ensure the achievement of essential relationships, synthetic identities, nor, of course, will we be able to establish true didactic "theorems" (unless we stop treating them as people and consider them merely as objects or laboratory animals, in which case we could do it) (Gallastegui, 2002).

All of the above are characteristics of the human sciences, as already stated in the previous section.

A distinction must be made between techniques and science; both are first-order knowledge, and, according to materialist philosophy, they are of a manual operative nature. That is, they imply the performance of operations and transformations on bodies, the difference lies in that techniques must necessarily be oriented towards practical purposes, while, for the sciences, this characteristic is not an essential requirement.

In the human sciences, as already discussed, the elimination of the operative subject is not possible because we work on fields of terms that, in themselves, are operatively locked by other subjects, prior to the possible operations of the person who investigates. Although it is true that the fields of any science have always been worked on by operations prior to science itself (operations of an artisanal and technological nature, which often lead to thinking, erroneously, that DM, as happens with other human and social sciences, is a technique or an art).

These operations do not play the same role in the human sciences as in the natural sciences. Gallastegui (2002) tells us that, for these, the instruments have become the authentic operators that allow the terms or elements of their fields to be constructed. In the social and human sciences, the role of these devices is played exclusively by the human subjects themselves. They are the ones who assume, exclusively, the role of operators and who construct or configure the terms (in DM, for example, teachers and students, as agents of cognitive behaviors).

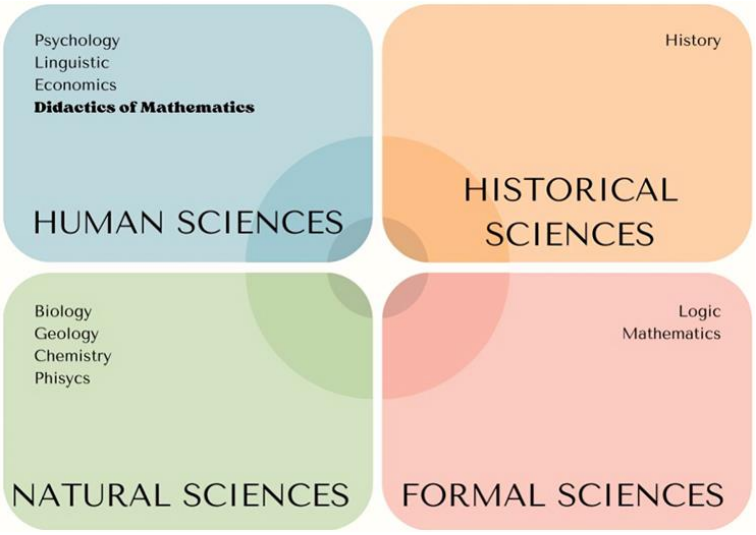

Figure 1. Classification of the sciences (Source: Authors' own elaboration)

Table 1. Coordination proposed by Alvargonzález (2023b)

Operating α states	Sciences of simple intelligence
Human techniques of operative co-determination	Medium science
History	Vision science

FINAL CONSIDERATIONS

From the arguments presented above, we can conclude that DM is not a technique but a human science, which will obviously continue to consolidate over time and form more and more paradigms.

Figure 1 shows a diagram that demonstrates the classification of categorial closure, featuring some examples of sciences, and how they are classified.

Bueno (1972) had several works writing about the human sciences; however, where he makes it most evident is in the 1976 work on the "egnoseological statute of the human sciences" Here, he discusses the scientific nature of these sciences and proposes a criterion of demarcation to distinguish their differences and distinctive features compared to the natural and formal sciences. The criterion was internally gnoseological, meaning it looked at how the sciences functioned inside, which was previously discussed with the characterization of the double plane operative.

Bueno (1972) coins a methodology that calls the situations of the natural sciences "alpha" and the human sciences "beta," where in the human sciences there are situations of both alpha and beta. Bueno (1972) proposes a coordination which is later taken up by Alvargonzález (2023b) where he proposes the coordination, as shown in **Table 1**.

Furthermore, Bueno (1972) adds that the human sciences, in general, their operations will be classified in this middle science, where we find human techniques of operational co-determination.

In this work, we did not deal with the methodologies and with this coordination proposed by Alvargonzález (2023b), but it certainly seems important to do so to better understand the epistemology of DM, analyze which operations carried out within this science can be classified into operational alpha states. And another important question is: Do teaching-learning techniques enter into human techniques of operational co-determination? This could be analyzed in another more robust work on the epistemology of DM.

All of this, we consider, could help the development, refinement, and consolidation of DM as a science, which, as we have already discussed, is still young.

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