Innovación Docente e Investigación Educativa en la Sociedad del Conocimiento

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CAPÍTULO 8

RENEWING THE PEDAGOGICAL FORMATION OF TEACHERS BY USING THE MANIPULABLE MATERIALS

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1. INTRODUCTION

The area of mathematics is one of the most socially valued, due to its instrumental character (Talis, 2014). From education policies, a lot of emphases is placed on their teaching, being one of the main areas of the curriculum. However, its abstract component places it as one of the most difficult areas for students (Sotos, 2016).

With a view to reducing the learning difficulties of students in this area of knowledge, manipulable materials arise to help, advise and decode those eminently abstract contents (Gairín-Sallán & Fernández-Amigo, 2015). In fact, the use of manipulable materials is not unique to the area of mathematics, but also takes on great prominence in the rest of the areas of knowledge, as they arise as facilitators of learning. Through manipulation, the child explores, experiments, learns and understands the reality around him, and by extension, the contents (Novo-Martín, 2018).

Before proceeding, it seems appropriate to provide a definition of manipulable materials, with a view to understanding the teaching possibilities offered to an inexperienced or over-experienced teacher when responding to the needs of their students.

There are many conceptions when defining manipulable or manipulative materials, some authors define it as tools that the teacher provides students to observe, understand and interpret concepts (Caldeira, 2009), others as facilitators of learning, because they transform the abstract into something concrete and tangible, through manipulation, contributing to the construction of meaningful learning by students (Canals, 2001). Both definitions include a common denominator, which is useful for math teachers to incorporate them into their teaching practices to achieve meaningful learning among their students.

Within manipulable materials, different classifications can be established, for example, depending on their initial purpose, they can be differentiated between structured and unstructured materials. While the former has been designed specifically for the area of mathematical education, the latter constitute materials initially designed for other areas of knowledge, but subsequently used in the area of mathematics. In both cases, the dominant concept of manipulable material is the one that considers them as a learning facilitator tool, through their repeated use by children in the classroom (Daro, Mosher & Corcoran, 2011).

Precisely the usefulness they have shown in the classroom has made many researchers dedicated time to deepen their effectiveness as innovative learning strategies (Clements, 2015; Fernandes da Silva, Pietropaolo & Font, 2015). However, different research has shown that the use of this type of resources requires the teacher to have a pedagogical knowledge of them (Murillo, Román and Atrio, 2016). Not only does it necessary for teachers to have knowledge of the content susceptible to teaching, it must also have a pedagogical knowledge that allows them to identify strategies and tools that facilitate the learning of their students (Arends, 2008). In addition, by dominating the scientific and didactic knowledge, teachers must know how their students learn, with a view to adjusting their teaching to their characteristics and needs (Rojas, Flores and Carrillo, 2015), respecting the principle of individualization (Garcia-Martínez, 2015). In the design and implementation of the teaching and learning processes, it is part of what the student already knows, to gradually increase the complexity of the content that can be taught

and produce changes in it, which allow him to become familiar with the mathematical concepts, while building his own knowledge (Daro, Mosher & Corcoran, 2011).

Another aspect to consider is the crucial role that the teacher plays in developing his teaching exercise. The innovation and constant renewal of pedagogical practices must accompany the teacher, so they can develop the interest of the students to continue learning (Jiménez-Espinosa & Sánchez-Bareño, 2019). In this way, a wide range of researchers promotes the existence of variables as predictors of the success of student learning. Such as the teaching performance, the didactic resources used, the wide variety of teaching strategies and experimentation-manipulation as means to achieve the emergence and development of representative and conceptual capacities (Caldeira, 2009).

In turn, there are other conditions that should be considered prior to the design and programming of instructional processes, like the selection of resources and teaching tools, some authors suggest that decisions on the selection of materials should be made according to the characteristics of the students, the academic level and the complexity of the contents (Gómez, Mediano, Chichón & Cabrero, 2019). Consequently, it is noted that the conduct of a didactic analysis on the materials to be used for the acquisition of mathematical content, not only allows to evaluate the actual effectiveness of the instruments to teach specific concepts, but allows innovations in the classroom that ensure a better understanding of students of mathematical knowledge (Zorro, 2019).

These approaches have been addressed from the field of research in the didactics of mathematics. For example, the study developed by Fernandes da Silva, Pietropaolo & Font (2015), approached mathematical teaching from the perspective of the teacher in training. In particular, the purpose of their study was to *investigate the knowledge of these future math teachers about the appropriate use of material resources in the teaching and learning process* (p. 1209). It is crucial for them that teachers have a mediational knowledge, in which they use various materials and technologies, to teach mathematics. Based on manipulative material resource indicators inspired by other research (Godino, Batanero, Rivas and Arteaga, 2013), they concluded that the use of physical spaces (mathematics lab) and manipulable materials improved learning students with special educational needs. Another crucial aspect is the choice of manipulable materials (Novo-Martín, 2018), not only because a good choice of materials decreases learning difficulties

related to mathematical abstraction, but also because they also diminish their reluctance towards this area of knowledge.

Finally, the inclusion of Information and Communication (ICT) technologies in student learning processes are essential. In research developed by Tadeu & Brigas (2018), on the benefits of the use of ICT, they claim that the exponential growth of the Internet and ICT, requires educational agents to become aware of educational possibilities and thus incorporated them into the classroom, to ensure a balance between society and school.

2. METHOD

The purpose of the research was to know and compare the perception that teachers in Primary School Education have about the use of manipulable materials. To this end, a descriptive, exploratory and comparative study was carried out with primary school teachers in Spain and Portugal. The research objectives are specified below:

- To understand which manipulable materials teachers use;
- To know what is the frequency of use of this type of material;
- To understand the importance that teachers attach to their use.

The study used 133 primary school teachers, being 85 Spanish (64%) and 48 Portuguese (36%).

2.1. Procedure

For the selection of study participants, we contacted the directors of the primary schools in the cities of Bragança (Portugal) and Granada (Spain), requesting their collaboration in the research. The objectives of the research were explained and we encouraged teachers to participate, assuring them feedback of the results. Once the invitation to participate was accepted, we explain that the questionnaire could be answered in paper or online, through the Google Form platform. In turn, we send to each an email with a formal invitation to participate in the investigation, as well as informed consent, ensuring confidentiality and anonymity in the processing of the data obtained.

2.2. Instrument of research

The instrument used was a Likert-type ad hoc questionnaire, with five answer options (with values between 1 and 5), of 89 items. It was designed for practicing teachers, it has two distinct parts identified. The first one, dedicated to sociodemographic data (age, service time, professional situation, activity it exercises and initial training), the second, they were asked several things, among them, and related only to this document: to indicate their opinion on the use of Didactical Materials and what was their vision regarding Mathematics. It was used the statistic package SPSS V. 24 to make a descriptive statistic and also a cross table relation between some of items point before.

3. RESULTS

In this study, 133 primary school teachers participated, 64% (85) from Spain and 36% (48) from Portugal, Figure 1.

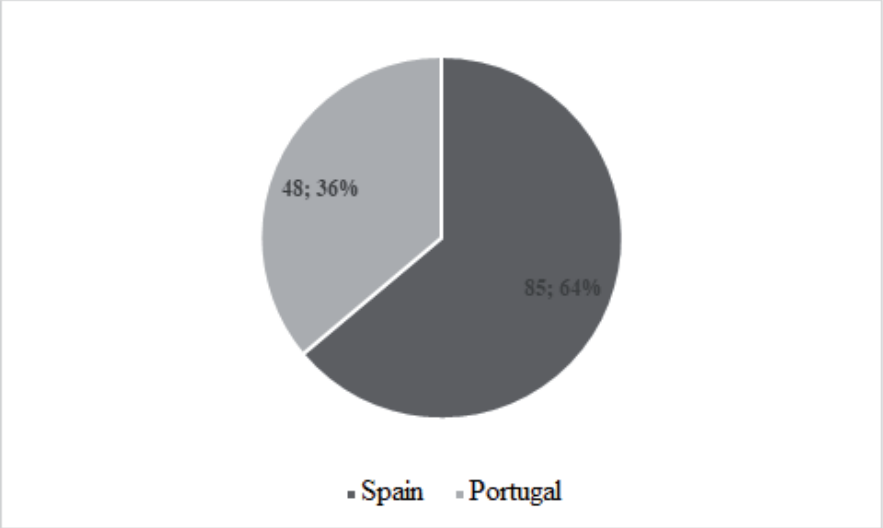

Figure 1. Characterization of the country.

Regarding the professional situation of Spanish teachers, it is observed that 40% (34) were of the permanent type; 36% (31) of the private-concerted type and 24% (20) interim teachers.

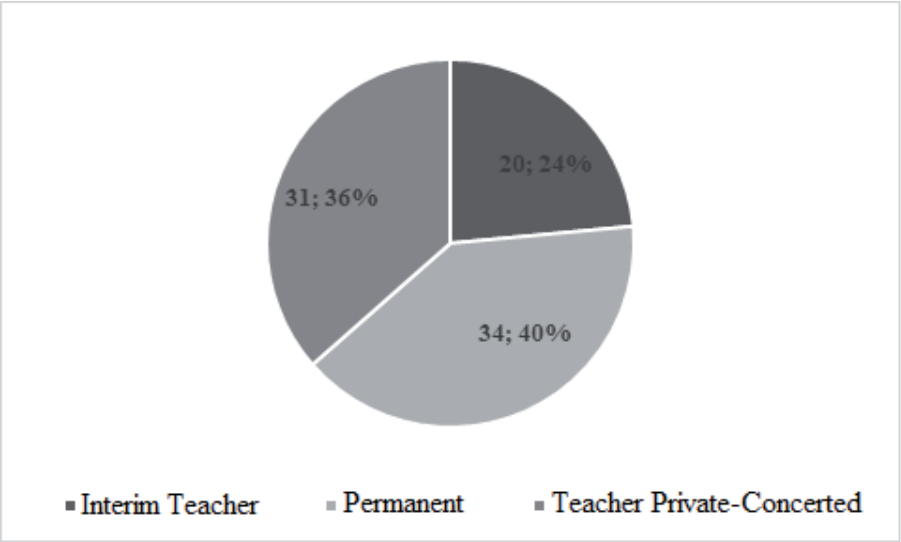

Figure 2. Characteristic of the professional situation of Spanish teachers.

In the case of Portuguese teachers who are part of the study, their professional situation is characterized as follows: 52% (25) belonged to the definitive board and 48% (23) to the pedagogical zone.

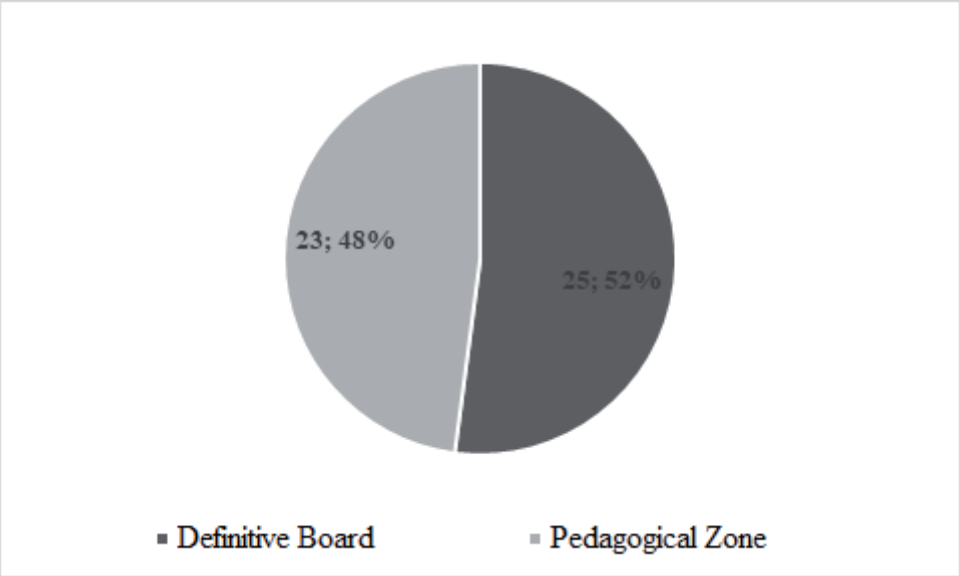

Figure 3. Characteristic of the professional situation of Portuguese teachers.

Table 1 shows the age of the teachers surveyed by country. Spanish teachers are considerably younger because they have an average age value of 35.02 years with standard deviation of 10.18 years from a minimum of 22 years and a maximum of 60 years. In turn, Portuguese teachers have a mean age of 53.71 years with a standard deviation of 7.61 years from a minimum of 35 years and a maximum of 66 years. It is registered that 50%

of the Portuguese teachers surveyed are at least 56.5 years old, while 50% of Spanish teachers are at least 30 years old.

Table 1

Characterization of Age

Country	Minimum	Maximum	Median	Average	Standard Deviation
Spain	22	60	30,0	35,02	10,18
Portugal	35	66	56,5	53,71	7,61
Total	22	66	42,0	41,77	12,95

Regarding the service time, Table 2, it is observed that Spanish teachers have an average of 9.96 years with a standard deviation of 9.91 years. On the other hand, Portuguese teachers have an average service time of 27.69 years with a standard deviation of 7.88 years. It should be noted that 50% of Portuguese teachers surveyed have at least 30 years of service time, while 50% of Spanish teachers have at least 6 years of service time.

Table 2

Service time characterization

Country	Minimum	Maximum	Median	Average	Standard Deviation
Spain	0,0	38,0	6,0	9,96	9,91
Portugal	12,0	39,0	30,0	27,69	7,88
Total	0,0	39,0	17,0	16,36	12,55

Figure 4 shows the characteristic of the activities developed by the teachers. It is observed that in both countries most teachers are exclusively in teaching (85.42% - Portuguese and 64.71% Spanish). In turn, 28.24% of Spanish and 4.17% of the Portuguese accumulate teaching and management; 2.35% of Spanish and 10.42% of Portuguese accumulate teaching with other activities and there are three teachers in Spain only dedicated to management and one dedicated to research.

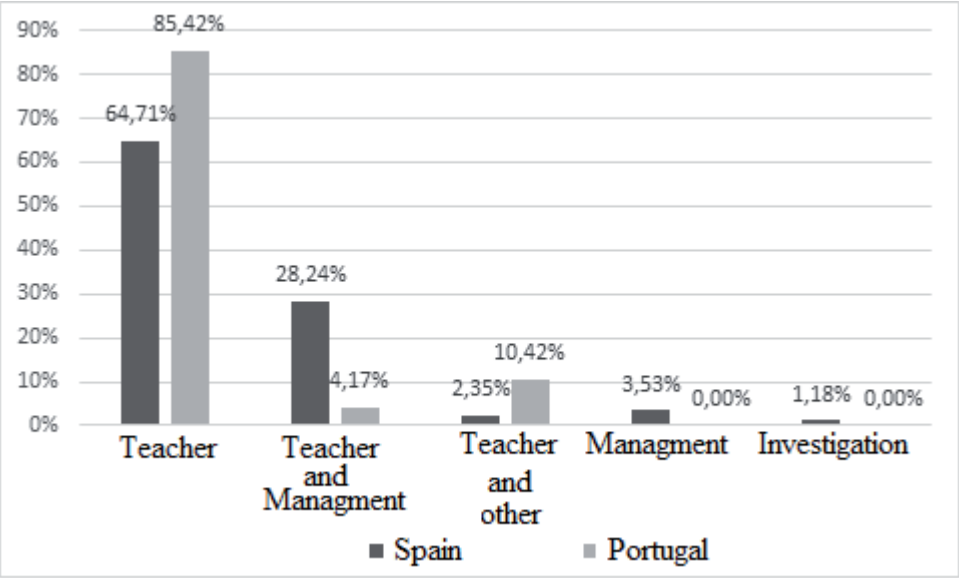

Figure 4. Characteristic of the activity carried out by teachers.

With regard to the initial training of teachers, Figure 5 shows that 60% of Spanish teachers have a bachelor's degree; 29.41% are graduated and 10.59% have master's degree. In the group of Portuguese 35.42% had the bachelor's degree; 60.42% are graduated and 4.17% have master's degree.

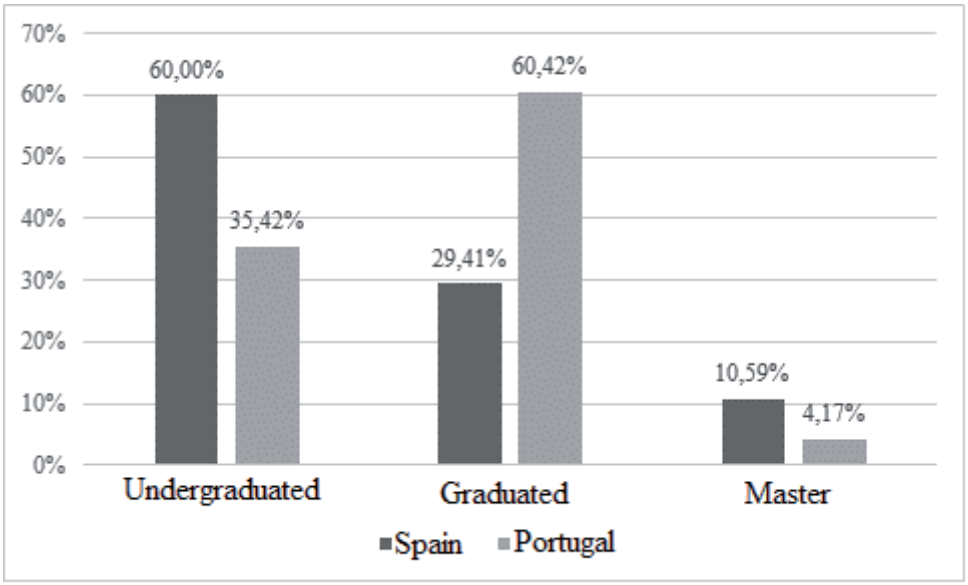

Figure 5. Characteristic of the initial training of teachers.

Following, we present the data regarding the questions 1 and 2 of the second part of the questionnaire, this data were analysed with respect to the answers collected from the group of teachers.

In Table 3 we have the results of crossing teachers' opinion regarding didactic material, according to the country where they teach, as well as the results of the test. Because of the impossibility of applying the Chi-Square test, Fisher's exact test was used.

It is observed that most Spanish teachers, 85.9%, as well as most Portuguese teachers, 66.7%, agreed that teaching material is all that leads to learning. Meaning the teacher's origin is statistically associated with agreement of this statement, (), since more Portuguese teachers disagreed with the statement of what was theoretically expected. Regarding the fact that the teaching material corresponds to everyday objects it is observed that most Spanish teachers, 63.5%, as well as most Portuguese teachers, 68.8% agreed that teaching material is all that leads to learning. However, at a significance level of 5% it was concluded that the teacher's origin is statistically associated with this statement, (), since more Spanish teachers were observed expressing indecision with the statement of what was theoretically expected.

Regarding the consideration of teaching material such as: it is a set of objects or things that the student is able to feel, manipulate; corresponds to objects used to present mathematical ideas; corresponds to resources that allow the teacher to develop a student-centred teaching; intends to develop in students a positive attitude towards mathematics and corresponds to a configured object, in order to materialize mathematical structures it was concluded that the opinions expressed are identical between Spanish and Portuguese teachers, high percentages of agreement in each possibility are observed. Due to the application of the appropriate test, it was confirmed that statistically the opinion obtained was independent of the country where the teachers performed the activity.

Table 3

Crossing teachers' opinion on teaching material

Didatical Material	Country			Total	Qui-Square
	Spain	Portugal			
	n(%)	n(%)	n(%)	ET(p)	

It's all that leads to learning		4(4,7)	10(20,8)	14(10,5)	9,293 (0,010)
		8(9,4)	6(12,5)	14(10,5)	
		73(85,9	32(66,7)	105(78,9)	
		85(100)	48(100)	133(100)	
It is a set of objects or things that the student is able to feel, manipulate		3(3,5)	2(4,2)	5(3,8)	1,993* (0,412)
		7(8,2)	1(2,1)	8(6,0)	
		75(88,2)	45(93,8)	120(90,2)	
		85(100)	48(100)	133(100)	
Matches everyday objects		5(5,9)	9(18,8)	14(10,5)	9,125 (0,010)
		26(30,6)	6(12,5)	32(24,1)	
		54(63,5)	33(68,8)	87(65,4)	
		85(100)	48(100)	133(100)	
Matches objects used to present mathematical ideas		11(12,9)	12(25,0)	23(17,3)	4,641 (0,098)
		18(21,2)	5(10,4)	23(17,3)	
		56(65,9)	31(64,6)	87(65,4)	
		85(100)	48(100)	133(100)	
Corresponds to resources that allow the teacher to develop a student-centered teaching		1(1,2)	2(4,2)	3(2,3)	1,806* (0,449)
		11(12,9)	4(8,3)	15(11,3)	
		73(85,9)	42(87,5)	115(86,5)	
		85(100)	48(100)	133(100)	
It aims to develop in students a positive attitude towards mathematics		1(1,2)	3(6,3)	4(3,0)	2,656* (0,271)
		5(5,9)	2(4,2)	7(5,3)	
		79(92,9)	43(89,6)	122(91,7)	
		85(100)	48(100)	133(100)	

Corresponds to a configured object in order to materialize mathematical structures		5(5,9) 6(7,1) 74(87,1)	5(10,4) 8(16,7) 35(72,9)	10(7,5) 14(10,5) 109(82,0)	4,278 (0,118)
		85(100)	48(100)	133(100)	

Note. n - absolute frequency observed; % - relative frequency; ET - test statistics; p- proof value; *- Fisher's exact test.

Table 4 shows the results of the teacher's origin crossing (Spanish or Portuguese) with the opinion about the view of mathematics (second question, of the second part of the questionnaire). Regarding the fact that mathematics corresponds to a knowledge under construction, which, in the course of the interaction of individuals with others and with the world, is constantly elaborated and systematized, all Portuguese teachers expressed agreement while 67.1% were Spanish teachers who agreed. By applying the chi-square test, (), it was concluded that this view on mathematics was statistically associated with the teacher's origin.

As far as mathematics corresponds to a finished knowledge situated on an abstract level it is observed that 51.8% of Spanish teachers agreed, while 94.9% of Portuguese teachers disagreed. There is an imbalance between teachers from different countries, so by the chi-square test, (), it was concluded that the origin was statistically associated with this view on mathematics.

Regarding mathematics being associated with their own methods of study, research and information organization, it is observed that most Spanish teachers, 84.7%, as well as most Portuguese teachers, 83.3% agreed with this view. However, at a significance level of 5% it was concluded that the teacher's origin is statistically associated with agreement with this statement, (), since more undecided Spanish teachers were observed than was theoretically expected.

Regarding mathematics being associated with the acquisition of isolated knowledge and the rule domain it is observed that 47.1% of Spanish teachers agreed, while 79.2%

of Portuguese teachers disagreed. There is an imbalance between teachers from different countries, so by the chi-square test (χ=31,793; p=0.000), it was concluded that the origin was statistically associated with this view on mathematics.

Table 4

Crossing teachers' opinion on the view of mathematics

Mathematics		Country		Total	Qui-Square ET(p)
		Spain n(%)	Portugal n(%)	n(%)	
It corresponds to a knowledge under construction, which, in the course of the interaction of individuals with other	Disagree	17(20,0)	0(0,0)	17(12,8)	20,028 (0,000)
	Indecision	11(12,9)	0(0,0)	11(8,3)	
	Agree	57(67,1)	48(100)	105(78,9)	
	Total	85(100)	48(100)	133(100)	
Corresponds to a finished knowledge situated on an abstract plane.	Disagree	20(23,5)	31(64,6)	51(38,3)	24,740 (0,000)
	Indecision	21(24,7)	10(20,8)	31(23,3)	
	Agree	44(51,8)	7(14,6)	51(38,3)	
	Total	85(100)	48(100)	133(100)	
It is associated with own methods of study, research and information organization …	Disagree	0(0,0)	4(8,3)	4(3,0)	7,438* (0,016)
	Indecision	13(15,3)	4(8,3)	17(12,8)	
	Agree	72(84,7)	40(83,3)	112(84,2)	
	Total	85(100)	48(100)	133(100)	

It is associated with the acquisition of isolated knowledge and the rule domain.	Disagree Indicision Agree	26(30,6) 19(22,4) 40(47,1)	38(79,2) 7(14,6) 3(6,3)	64(48,1) 26(19,5) 43(32,3)	31,793 (0,000)
	Total	85(100)	48(100)	133(100)	

NOTE. N -ABSOLUTE FREQUENCY OBSERVED; % - RELATIVE FREQUENCY; ET - TEST STATISTIC; P- PROOF VALUE; *- FISHER'S EXACT TEST.

4. DISCUSSION

In questions 1 and 2, belonging to the second part of the questionnaire relating to the exploratory study in question, and regarding the teachers' opinion concerning the didactic material there were some differences between Spanish teachers and Portuguese. The same happened in relation to his view on Mathematics. In the opinion of teachers on didactic material taking into consideration the country where they teach, 85.9%, of Spanish teachers and 66.7% of Portuguese teachers, agreed that didactic material is everything that leads to learning, fulfilling the function of guiding, exemplifying, illustrating, which agrees with the research of Zabala (Zabala, 1998). The author Graells (2000), stresses, furthermore, the fact that it is used; (i) facilitate the comprehension of content ii) constitutes a guide to learning; (ii) provide training and skills exercise; iv) captivate interest by motivating and involving students; v) its manipulation allows to evaluate the understanding of the contents; vi) provide simulations to students in order to go through three phases – observation, exploration and experimentation and vii) to design environments of expression and creation. In summary didactic material is everything that leads to learning, a fact that agree 63.5% of Spanish teachers and 68.8% of Portuguese teachers to associate it with everyday objects. These data allow us to realize that most teachers, from both countries, throughout the teaching-learning process, feel the need to use educational supports, called *teaching materials*, leading the student to feel, to manipulate objects in order to present mathematical ideas; that allow the teacher to develop a student-centred teaching. Among these materials we highlight, according to Vale (2000) *white board, books, beans, ice cream sticks, graphics, solids, simple and graphic calculators, computers, etc. [...] video and internet, among others*. This makes the student to feel, seeing, analysing, manipulating; corresponding to objects used to

present mathematical ideas; also this corresponds to resources that allow the teacher to develop a student-centred teaching that intends to develop in the students a positive attitude towards mathematics in order to materialize mathematical structures. Within this set of teaching materials, the same author integrates structured manipulated materials, such as: *geoboard, multibase material and cuisenaire bars* (Vale, 2000, p. 64).

Regarding the teachers' opinion of their view of mathematics, respondents report that mathematics corresponds to a knowledge under construction, which, in the course of the interaction of individuals with others and with the world, is constantly elaborated and Systematized. All Portuguese teachers expressed agreement with these aspects while only 67.1% of Spanish teachers agreed. However, the authors Moreira & Martinho (2015) also argue that learning should be built, starting from concrete to abstract, and stressing the importance of manipulated materials in this process. They also show that learning should be based on experience, that is, the construction of concepts constitutes as a long process that requires the student an active role and that evolves from concrete to abstract. This progression happens regardless of the age or specificity of the content. As for the fact that mathematics corresponds to a finished knowledge but situated on an abstract plane it is observed that 51.8% of Spanish teachers agreed, while 94.9% of Portuguese teachers disagreed. There is an imbalance between teachers from different countries here. The foundation of the opinion of Portuguese teachers is governed by the fact that "teaching mathematics is complex, requiring teachers to have a deep understanding of knowledge and a clear view of how learning this knowledge, students develop and progress throughout the years of schooling" (NCTM, 2017, p.7).

It is important to mention that mathematics is associated with own methods of study, research and the organization of the information, to the understanding of concepts, fluency of procedures, competence in strategies, adequacy of reasoning (NCTM, 2017). These facts are observed in most of Spanish teachers, 84.7%, as well as most Portuguese teachers, 83.3%, who agreed with this view.

Regarding mathematics being associated with the acquisition of isolated knowledge it is observed that 47.1% of Spanish teachers agreed, while 79.2% of Portuguese teachers disagreed. There is an imbalance between teachers from different countries. However there are studies (Lampert, 2010; McDonald, Kazemi & Kavanagh, 2013) confirming that learning mathematics depends on many factors, related, among them what happens

in class, in the powerful practices that are at the basis of effective teaching, where collaborative work is worked to implement them.

5. CONCLUSION

The investigation carried out has proven how important manipulable materials are for the mathematics class. High percentages in both countries have placed it as a useful tool to consolidate student learning, decreasing their understanding difficulties in mathematics. Also, it has been found that this set of educational tools goes beyond specific materials designed for teaching purposes in this instrumental area.

Despite a positive disposition towards the incorporation of manipulable materials in the field, some problems remain. For example, teachers often wonder about a theory that supports the use of these tools for more abstract content. A scientific knowledge about mathematics is not enough; it is also important to have suitable pedagogical knowledge in order to include and design strategies and resources that enable students to learn.

In this regard, unanimity has been found when identifying manipulable materials such as: it is a set of objects or things that the student is able to feel, manipulate; corresponds to objects used to present mathematical ideas; corresponds to resources that allow the teacher to develop a student-centred teaching; intends to develop in students a positive attitude towards mathematics and corresponds to a configured object, in order to materialize mathematical structures. In this respect, despite having different epistemological positions on their conception of mathematics, most respondents claim to design and construct their own materials.

Based on the results obtained, future directions to be followed for successive studies will be oriented towards the expansion of the sample, in order to achieve a better understanding about the topic. This will provide a better explanation when designing teaching proposals based on different situations that require more materials and games. All of this will simplify the teachers' efforts to design instructional processes that contribute enough knowledge to guarantee the transition from the specific to the abstract level.

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