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Interdisciplinarity: A Pedagogical Practice in the Classrooms

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Abstract**—**The world is changing and, consequently, the young people need to acquire more sophisticated tools and skills to lead with the new societies' challenges. In the curriculum of the Portuguese education system, in the profile of students leaving compulsory education, the critical thinking and creative thinking are pointed out as skills to be developed, as well as the capacity of interconnect different knowledge and applicate them in different contexts and learning areas. Unlike primary school teachers, teachers specialized in a specific area sometimes reveal more difficulties in developing interdisciplinary approaches in the classrooms and, despite the effort, the interdisciplinarity is not a common practice in schools. Statements like "Mathematics is everywhere" are unquestionable, however, some math teachers continue to develop an abstract teaching of mathematics devoid of any connection with reality. Good mathematical problems in real contexts are promising in the development of interdisciplinary pedagogical practices. However, these problems are often addressed by teachers in multidisciplinary rather than interdisciplinary contexts or are not addressed at all due several reasons, which range from insecurity in working on disciplinary domains with which they are not comfortable to a lack of pedagogical resources. In this study this issue is approached through a case study involving Mathematics teachers, which, in their professional development scope, attended a training aimed at stimulating interdisciplinary practices in real contexts, namely related to the COVID-19 pandemic.

Keywords**—**Interdisciplinarity, Mathematics, professional development, teacher training.

I. Introduction

THE presence of Mathematics in our lives is unavoidable. Even those who consider themselves little skilled in this field are endowed with an innate mathematical talent, which is reflected in the actions of their own body. Thus, Mathematics reveals itself from what is intrinsic to us to what is extrinsic to us, this is evident in the surrounding reality in numerous examples. Constant evolution in various scientific or social domains, as well as the approach or resolution of various problematic situations that arise in everyday life are supported by Mathematics. During the period in which the world was surprised by the COVID-19 pandemic, the usefulness of Mathematics became evident in several situations, in the dissemination of daily data through the mass media, in the calculation of the transmissibility index, in the study of measures to combat the spread of the virus, among others.

Within the scope of the Meeting "Mathematics with Life: Different perspectives on Technology", organized by a Portuguese university, the workshop "Mathematical Aspects of the COVID-19 Pandemic" was designed and promoted, aimed at teachers in the 2nd and 3rd Cycles of Basic Education. This workshop aimed to present information about the COVID-19 pandemic and show how it is possible to use it to create real problematic situations, integrating various areas of knowledge, including Mathematics. Among the several intentions of this workshop, one of them was to understand whether the type of tasks and resources the participants usually implement in their classrooms improving the integration of different knowledge areas. In this sense, the presented study has as aim to answer to the following research question: How prevalent are tasks, practices and resources that promote interdisciplinarity, in the classroom of a group of mathematics teachers?

II. Theoretical Framework

A. Challenges in Teaching Mathematics

Expressions like "Mathematics is everywhere" or "Everything is Mathematics" reveal the transversality of Mathematics in the most varied situations in our lives, from the most practical situations, such as paying for a purchase and receiving change, to less obvious examples as its application in phenomena's description such as the tides. Although mathematical knowledge is essential in students' lives, and is present in simple everyday actions, Mathematics is one of the subjects in which they face most difficulties. The abstract nature of Mathematics can be seen as a learning obstacle, if teachers do not provide students with contexts that represent concepts and give them meaning. In fact, the use of real contexts, integrating different knowledge areas, is promising for the conception, understanding and application of mathematical concepts by students. Since mathematical knowledge and skills are transversal to several subject areas, interdisciplinary contexts and practices should have a privileged place in mathematics classes. Integrated curricula provide more relevant learning experiences, and the interdisciplinary mathematical activities contexts allow students apply mathematical knowledge in practice through experimentation, observation, and conjecture's formulations [1]. Furthermore, the interdisciplinarity can orient disciplinary resources and learning objectives to common educational goals [2], providing the acquisition of necessary skills for a citizen of the 21st century.

Despite recognizing interdisciplinary practices as a condition for the development of learnings, "in the practice of didactic

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action, the idea of interdisciplinarity seems to frighten teachers" [2, p.24]. Teachers' hesitation, regarding interdisciplinary practices, is due to several assumptions, such as: teachers of different disciplines have distinct disciplinary practices and learning outcomes in view; the difficulty in defining a common object; the alienation between disciplines; the professional identity; among others [3]. Faced with the various challenges that education poses to teachers, they cannot take refuge in their own difficulties, since their instructional skills influence the students' learning. As pointed out by educators and researchers, the teachers' performance impact goes beyond students' academic achievement alone, since highly qualified teachers not only support the improving of students' achievement, but also provide instructional contexts and tasks that regarding the social-emotional skills development and critical thinking [4], [5].

Several international organizations have been providing guidelines on "how young people can navigate their lives and their world" [6, p.4], being the Organization for Economic Co-operation and Development (OECD) one of them, suggesting an interdisciplinary knowledge as a principle for the future of education systems, arguing that "Disciplinary knowledge will continue to be important, as the raw material from which new knowledge is developed, together with the capacity to think across the boundaries of disciplines and connect the dots." [6, p.5].

B. Interdisciplinarity

In initial or continuing teacher training, when the interdisciplinarity is approached, the conception presented by students or trainees is often based on practices that involve several disciplinary areas without a deep interconnection between them. However, an interdisciplinary practice is much more than that, such practices imply identifying the relationships that exist between disciplines and common objectives, and not the attempt to join or "destroy" disciplines to create a possible meta-discipline [7]. In fact, there is a variety of conceptions about interdisciplinarity, which is due not only to a possible lack of knowledge about the subject, but also to some subjectivity associated with it. For instance, Lenoir [8] considered the interdisciplinarity as a polysemous concept, whose interpretations may differ based on different cultural logics.

Several educators and researchers have presented perspectives on interdisciplinarity and the related concepts of pluridisciplinarity and transdisciplinarity (e.g., [9]-[12]). According to Pombo [13], the boundaries between these concepts are not established for those who use them, for those who study them, nor for those who seek to define them. However, in [11], Pombo presents a definition proposal for these three concepts: pluridisciplinarity is the minimum extreme of integration disciplinary, which implies bringing together or establishing some type of coordination between disciplines from a perspective of mere parallelism of points of view; when we overcome the dimension of parallelism, of combining in a coordinated way, and move towards a combination, a convergence, a complementarity between disciplines, an intermediate level is reached, the interdisciplinarity; when we approach a point of fusion, of unification, when convergence disappears, we move to a holistic perspective, which characterizes transdisciplinarity.

Regarding mathematics education, the interdisciplinarity encompasses multidimensional types of integrated learning. The STEM education, that emerged in response to the need to increase student interest and skills in Science, Technology, Engineering, and Mathematics is considered an interdisciplinary approach [1]. Posteriorly have emerged the STEAM education, in which the arts are articulated with STEM subjects for the purpose of improving student engagement, creativity, innovation, problem-solving skills, and other cognitive benefits [14].

C. Teachers' Professional Development

Societies are constantly changing and the school, as an integral part of them, must keep up with them. Teachers must respond to new challenges that arise constantly. The perspective of inclusive education, considering students' cultural, cognitive, and socio-emotional differences, or the development of essential skills for 21st century citizens, are aspects that have challenged teachers' pedagogical practices and stimulated a constant professional development. According to OECD [15, p.49], the professional development can be provided in several ways, namely, "through external expertise in the form of courses, workshops or formal qualification programmes, through collaboration between schools or teachers across schools (e.g. observational visits to other schools or teacher networks) or within the schools in which teachers work". It is important and necessary to promote teachers' professional development as a means to increase teaching quality and improve students' academic and socio-emotional skills [16], in fact, there is broad agreement that teachers' knowledge plays an important role in providing high-quality learning opportunities to students as well as fostering students' learning (e.g., [17], [18]).

Faced with a wide range of training offers for the of teachers' professional development, Grunefeld et al. [19, p.2], based on various research, argue that any professional development experience must provide participants with: "the opportunity to acquire knowledge and skills relevant to the domain; the opportunity to gain experience with dealing with change and novel tasks; multiple opportunities for deliberate practice in the domain". Although the teacher is the main subject of their own professional learning, teacher training is as well responsible for this learning, having the challenge of finding appropriate ways to favor the natural processes of teacher professional development [20], [21]. The provision of training within the scope of teachers' professional development must consider the existence of "highly qualified teachers in schools that not only support students in improving their achievement, but also provide instructional contexts that help students to develop their social" and emotional skills, and their critical and creative thinking [5, p.583].

III. Method

A. Workshop's Description

The "Mathematical Aspects of the COVID-19 Pandemic"

workshop was held remotely, via videoconference through Colibri platform (Zoom), lasting three hours, with the participation of ten teachers who signed up voluntarily. In this workshop, possible teaching and learning contexts were presented and proposed activities based on emerging mathematical aspects of the COVID-19 pandemic situation, envisaging an interdisciplinary approach, using digital technological means, were explored.

The workshop began with the filling out an individual questionnaire on the Google Forms platform, focused on teachers' professional characterization and pedagogical practices. After a brief contextualization of the session's theme and its dynamics, the teachers were distributed into simultaneous rooms, forming two groups with three members each and one group with four members. The constitution of the groups considered the existence of elements that utilized frequently the GeoGebra software, since the proposed tasks, presented below, involved its use.

Problematic *Situation* 1

We consider the following dialogue between two friends, Maria and Joana, during the morning school-break:

- Joana, we are as close to each other as possible, complying with the rule of the Portuguese Directorate General for Health, on the minimum physical distance. If Carlos arrives, for him to be as close to both of us as possible, he can only choose two locations.
- Mary, I don't agree with you! Carlos can choose many more places.

1. Who is right? Why?
2. Connecting, by straight lines, the minimum social distance positions occupied by the 3 friends, we obtain a polygon. What polygon is it? Describe it.
3. As soon as the minimum social distance positions are fixed for the 3 friends, there comes a fourth friend, Henrique.

3.1. How many minimum social distance positions can Henrique occupy?

3.2. Joining the minimum social distance positions of the 4 friends, a polygon emerges. What polygon is it? Describe it, in few words.

4. As soon as the minimum social distance positions are fixed for the 4 friends, there comes a fifth friend, Daniel.

4.1. How many minimum social distance positions can Daniel occupy?

4.2. Joining the minimum social distance positions of the 5 friends new polygons emerge. What polygon are they? Describe them, briefly.

5. As soon as the minimum social distance positions are fixed for the 5 friends, there comes a sixth friend, Joaquim.

5.1. Guess the number of minimum social distance positions that Joaquim can occupy? Check whether your conjecture is true.

5.2. What polygon(s) can be constructed when setting minimum social distance positions for the 6 friends?

Suggestion: Using GeoGebra software, or appropriate geometric physical instruments, to represent the situations.

Problematic Situation 2

In a vaccination room, a square-shaped recovery zone of *n*-by-*n* meters is marked, with *n* a natural number ranging between 4 and 10.

1. Determine, according to the value of *n*:

1.1. The maximum number of available seats, following a quadrangular lattice distribution, respecting the minimum social distance, that is, two meters between people.

1.2. The maximum number of available seats, following a regular triangular lattice distribution, respecting the minimum social distance.

1.3. Can we say that one of the referred distributions (quadrangular or regular triangular) is more efficient than the other? Justify.

Suggestion: In the following link you can find a model for what is described in question 1: https://www.geogebra.org/m/g79m2gac [22]

2. Determine the general term of the sequences, *Un* and *Vn*, such that, for each natural number *n*, *Un* and *Vn* corresponds to the maximum number of available seats, of a quadrangular format recovery zone of *n*-by-*n* meters, following a quadrangular lattice distribution and a regular triangular lattice distribution, respectively, respecting the minimum social distance.

After the tasks were solved and discussed in a large group, it was proposed to fill out another individual questionnaire, on the Google Forms platform, with the aim of evaluating and reflecting on participation in the workshop.

B. Research Question and Objectives

The implementation of this workshop had several intentions, one of which was to understand whether the type of tasks and resources implemented in the participants' classrooms promoted the integration of different areas of knowledge. If this does not happen as often as desired, it was our intention to identify obstacles or difficulties experienced by teachers in carrying out such pedagogical practices. Therefore, the presented study is based on the following research question: How prevalent are tasks, practices and resources that promote interdisciplinarity, in the classroom of a group of mathematics teachers? To answer the research question, the following study objectives were established: characterize the participants' pedagogical practices from an interdisciplinary point of view; identify any difficulties experienced by participants when implementing interdisciplinary contexts in their classes.

To infer a possible answer to the research question, a qualitative and quantitative case study [23] was developed, supported by a descriptive and interpretative approach [24].

C. Data Collection and Analysis

To collect the data on which this study is focused, a questionnaire was created on the Google Forms platform, that integrated questions divided into three sections: participants' characterization from a professional point of view; participants' pedagogical practices; potentialities of the COVID-19 pandemic context in teaching and learning Mathematics. The questionnaire was administered at the beginning of the session

and filled out individually by participants. When completing the questionnaire, participants consented the use of data for exclusive research purposes, with the guarantee of their confidentiality.

The data resulting from the questionnaire were organized into the following categories: participants' professional characterization; pedagogical practices implemented in their classes, subdivided into subcategories (nature of proposed tasks; teaching material types; knowledge areas used to promote interdisciplinarity in Mathematics teaching); difficulties and challenges associated with the implementation of interdisciplinary practices. Considering the nature of the questions of the questionnaire, a qualitative and quantitative analysis was carried out.

IV. Results' Presentation and Analysis

In this section, the collected data are presented and analyzed. According to the questions proposed in the questionnaire, the data are organized into the following categories: participants' professional characterization; participants' pedagogical practices; participant's difficulties and challenges in the implementation of interdisciplinary practices.

A. Participants' Professional Characterization

Regarding the academic training of the participants, the predominant area is mathematics – educational domain (8 participants). However, one participant has a degree in industrial engineering and management and another one in mechanical engineering. One of the teachers has also a master's degree and another one is currently pursuing a master's degree in mathematics for teachers.

Considering the educational levels they usually teach mathematics, 9 participants mentioned Secondary Education and only one the 3rd Cycle of Basic Education, being characterized in terms of professional time service as follows: 5 participants have between 10 and 20 years; 3 participants have between 21 and 30 years; 2 participants have between 31 and 40 years. We also note that the minimum professional time service observed was 14 years.

B. Participants' Pedagogical Practices

Regarding the pedagogical practices implemented in teachers' classes, the nature of the questions asked allowed us to subdivide the data into the following subcategories: proposed tasks nature; teaching material types; knowledge areas used to promote interdisciplinarity in Mathematics teaching.

Tasks Nature

The questions regarding the tasks that are usually proposed in the classroom by the participants focused on their context (real contexts; modeling problems; interdisciplinary contexts) and on the tasks type (involving information research; involving the exploration or investigation of concepts mathematical or properties). Next, we present the proposed questions and the respective results. In Figs. 1-5, we consider 1 as "never" and 5 as "always".

Question: How Often Do You Use Real Contexts to Approach Mathematical Content in Your Classes?

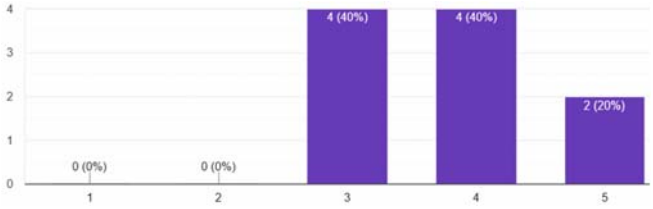

Fig. 1 Tasks involving real contexts

Analyzing Fig. 1, we verify that most participants consider frequently real contexts in the mathematical content approach.

Question: How Often Do You Promote Interdisciplinarity in Mathematics Teaching?

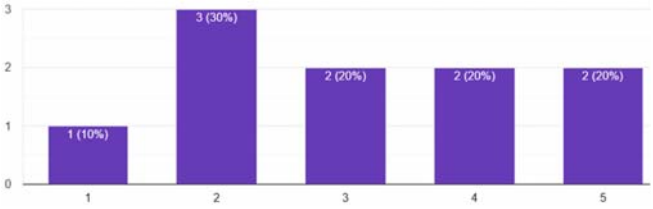

Fig. 2 Interdisciplinary practices

In Fig. 2 is verified a dispersion of data, in which 40% of the participants do not promote interdisciplinarity in their classes regularly.

Question: How Often Do You Implement Mathematical Modeling Problems in Your Classes?

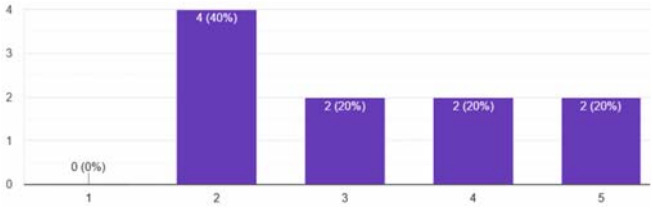

Fig. 3 Implementation of mathematical modeling problems

Through Fig. 3, most of the participants frequently propose mathematical modeling problems in their classes.

Question: How Often Do You Promote Research Activities in Your Classes?

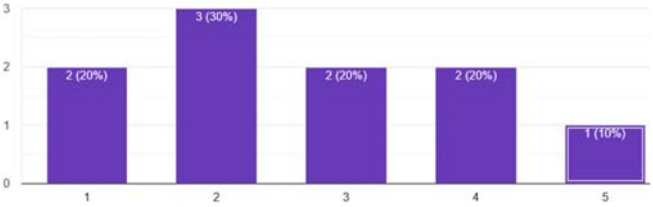

Fig. 4 Research activities

In this question, the presented data in Fig. 4 is quite dispersed, and it should be noted that half of the participants do not propose, or do not propose frequently, research activities.

Question: How Often Do You Propose Activities to Explore or Investigate Mathematical Concepts or Properties in Your Classes?

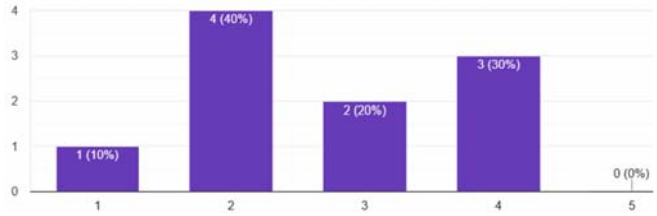

Fig. 5 Exploration and investigation activities

According to Fig. 5, half of the participants do not promote, or do not promote frequently, exploration or investigation activities on mathematical concepts or properties.

Teaching Material Types

Next are presented the proposed questions and the respective results, about the resource types used in the participants' classes. In Figs. 6 and 7, we consider 1 as "never" and 5 as "always".

Question: How Often Do You Use Literature, Videos, or News in Your Classes?

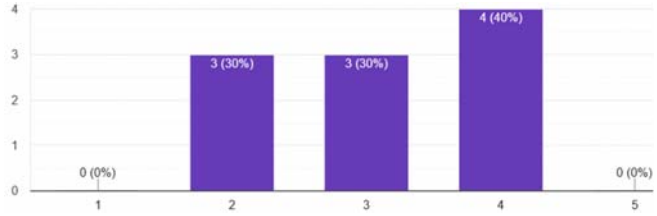

Fig. 6 Use of literature, videos, and news

According to Fig. 6, most of the participants use regularly resources such as literature, videos, or news in their classes.

Question: How Often Do You Use Dynamic Geometry Software or Other Technological Tools in Your Classes?

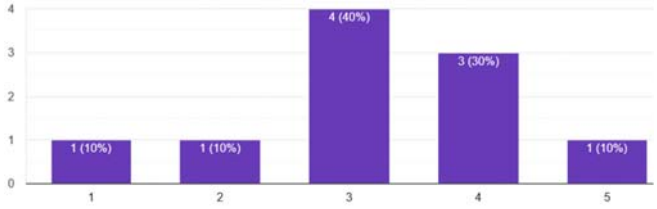

Fig. 7 Technological tools

From Fig. 7, we conclude that technological tools are used regularly by the most of participants in their classes.

Knowledge Areas to Promote Interdisciplinarity

When asked about examples of real contexts that usually approach in their classes in articulation with Mathematics, the participants mentioned: bank statements and bank loans simulations; elections; 2nd World War; exponential growth of plagues and pandemics; students' data (weight, height, among others); news for statistical treatment.

Regarding the knowledge areas that they usually use to promote interdisciplinarity in Mathematics teaching, the participants mentioned: Physics; Chemical; Computing; Natural Sciences; Sport; Geography.

C. Participants' Difficulties and Challenges in the Implementation of Interdisciplinary Practices

From a set of possibilities, participants identified those that they considered to constitute difficulties in implementing interdisciplinary practices. The results are presented in Fig. 8, in which the blue bars correspond to "yes" and the red bars to "no". In the graph, the letters represent the following possible reasons:

a) lack of resources (information; examples of tasks);
b) difficulty in working on other areas of knowledge;
c) difficulty in working Mathematics in an interdisciplinary way;
d) difficulty felt by students in establishing connections between different areas of knowledge;
e) the time that this type of activity requires;
f) difficulty in collaborating with teachers from other subject areas.

Participants could add other reasons that were not included in the options presented, however, none of them did so.

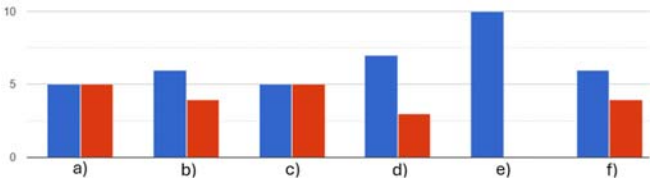

Fig. 8 Difficulties and challenges interdisciplinary practices implementation

From analysis of Fig. 8, we verify that the reasons most cited by participants are: difficulty in working on other knowledge areas; difficulty felt by students in establishing connections between different knowledge areas; difficulty in collaborating with teachers from other subject areas; and the time that this type of activity requires, being this the only reason cited by all participants.

V. Conclusion

The interests of today's young people are different from the interests of young people a few years ago, the same is verified with the needed skills to be developed having in view their integration into professional and social life. In this sense, the OECD [6] have been providing guidelines to response to the education's challenges, reinforcing namely the necessity to develop students' capacity to connect the disciplines and think across their boundaries. Although many studies recognize the role of the interdisciplinarity in learning's development, many teachers continue to experience difficulties in applying interdisciplinary practices in their classes for various reasons [2], [3]. Regarding this teachers' difficulty, it is important to promote professional development to improve their skills and increase the teaching quality [16].

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workshop were presented example of real contexts and tasks regarding interdisciplinary practices. Among the several intentions of this workshop, one of them was to understand how frequent in the participant mathematics teachers' classrooms are the tasks, practices and resources which promote interdisciplinarity. Data collection and analysis centered into the participants' pedagogical practices and the difficulties and challenges felt in the implementation of interdisciplinary practices. Regarding the tasks' nature frequently implemented in their classroom, we verified that most participants consider frequently real contexts in the mathematical content approach as well as mathematical modeling problems. However, 40% of the participants do not promote interdisciplinarity in their classes regularly. Considering the implementation of research activities, exploration or investigation activities on mathematical concepts or properties, half of the participants do not propose, or do not propose frequently task of this nature. About the teaching material resources, most participants regularly use literature, videos, news, and technological tools in their classes. When asked about the knowledge areas that they usually use to promote interdisciplinarity in Mathematics teaching, Physics, Chemical, Computing, Natural Sciences, Sport, and Geography were mentioned. The participants pointed out difficulties and challenges that they feel in the implementation of interdisciplinary practices, being the most reasons referred related with the difficulty in working on other knowledge areas and collaborating with other teachers, the students' difficulties in establishing connections between different disciplines, and the time required by this type of practices, being this the only reason cited by all participants.

Although this work is the result of a case study, we believe that these results are representative of what happens with teachers regarding interdisciplinary practices. In this sense, we consider it pertinent to focus on offering training on these practices for the professional development of teachers, with a view to providing them with knowledge and resources, demystifying some conceptions and motivating them towards more challenging teaching practices with more meaning for students.

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