




# Teacher Action and Student Action in Mathematics Classes Based on the Exploration of Learning Objects on Digital Board: Categorisations and Connections

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## ABSTRACT

**Background:** The methods by which mathematics content can be taught and learned using technologies and how they condition the production of mathematical knowledge have usually been the subject of our research. These investigations have allowed us to describe, understand and analyse the educational context in which we researchers are inserted, also allowing us to highlight the teacher's and the students' actions, their categorisations, and connections during the implementation of classes. These reasons motivated us to carry out this investigation. **Objectives:** To characterise the teacher's and the students' actions, highlighting their connections. **Design:** Qualitative research based on content analysis. Setting and participants: The research subjects were 1 teacher; 24 elementary school students, 10 students of the 6<sup>th</sup> grade and 14 of the 7<sup>th</sup> grade, and 12 high-school 3<sup>rd</sup> graders, all enrolled in the Paraná state network. **Data collection and analysis:** The actions were captured through field notes and video recordings, later transcribed. **Results:** In view of the information collected and the analyses carried out, 22 categories were evidenced for the teacher's action and 40 categories for the student's action. **Conclusions:** We proved that some of the teacher's actions triggered several other students' actions. However, we identified three categories of students' actions unrelated to the teacher's actions nor to the performance of the activity provided by the learning objects. In fact, such actions were provided by the learning environment in which students used technological resources.

**Keywords:** Teacher's action; Students' action; Math classes; Digital board; Learning objects.

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# Ação Docente e Ação Discente em Aulas de Matemática Fundamentadas na Exploração de Objetos de Aprendizagem na Lousa Digital: Caracterizações e Conexões

## RESUMO

**Contexto:** Habitualmente têm sido temas de nossas pesquisas os métodos pelos quais os conteúdos de Matemática podem ser ensinados e aprendidos mediante o uso de tecnologias e a forma como estas condicionam a produção do conhecimento matemático. Estas investigações nos têm permitido descrever, compreender e analisar o contexto educacional em que nós pesquisadores estamos inseridos, também possibilitando-nos evidenciar a ação docente e a discente, suas categorizações e conexões no decorrer da implementação das aulas. Estas razões nos motivaram a realizar esta investigação. **Objetivos:** Caracterizar as ações docente e discentes, evidenciando suas conexões. **Design:** Investigação qualitativa baseada na Análise de Conteúdo. **Ambiente e participantes:** Os sujeitos da pesquisa foram um professor; 24 alunos do Ensino Fundamental, sendo 10 do 6º ano e 14 do 7º ano; 12 alunos do 3º ano do Ensino Médio, todos integrantes da rede estadual paranaense. **Coleta e análise de dados:** As ações foram captadas por meio das notas de campo e das videografações, posteriormente transcritas. **Resultados:** Diante das informações coletadas e das análises realizadas evidenciaram-se 22 categorias para a ação docente e 40 categorias para a ação discente. **Conclusões:** Comprovamos que há ações do professor que desencadeiam diversas outras ações dos alunos. No entanto, identificamos três categorias de ações discentes que não possuem interrelação com as ações do professor e nem relação direta com a realização da atividade proporcionada pelos objetos de aprendizagem. De fato, tais ações foram propiciadas pelo ambiente de aprendizagem no qual os alunos utilizaram recursos tecnológicos.

**Palavras-chave:** ação docente; ação discente; aulas de matemática; lousa digital; objetos de aprendizagem.

## INTRODUCTION

The ways mathematics content can be taught and learned through technologies and how these condition the production of mathematical knowledge have been recurring themes in our studies in recent years. Mainly, we have been focused on characterising students' and teachers' actions when exploring learning objects (LO) on the digital board (DB). Such investigations allowed us to describe, understand, and analyse the researchers' educational context.

That said, the investigation whose results we present in this article stemmed from the following questions: What are the actions of students and mathematics teachers during the exploration of a LO on a DB in class? What

connections occur between teachers' and students' actions while exploring an LO on a DB?

Following the assumed objectives, we chose a qualitative research approach, adopting the content analysis (CA) procedures, as conceived by Moraes (1999), for data interpretation to characterise the actions of the investigated individuals and obtain answers to the preliminary questions raised.

Therefore, this study aims to characterise the actions of students and their mathematics teachers while exploring a LO on a DB, i.e., in classes based on the use of digital technologies (DT). The action is the focus of an investigative movement that encompasses a research programme for which the teaching action is the action the teacher performs in the classroom aiming at teaching and learning, and students' action is the activity that the students develop in the classroom, aiming to learn school knowledge. Besides typifying the students' and teachers' actions, we also highlight their connections.

For the classroom to become a space that produces knowledge, human actors –students and teachers– and non-human actors –media– must be present and active, triggering the teaching and learning process. We emphasise that this was the intentional environment provided to the students by the researcher teacher responsible for implementing the classes.

In the following sections, we will bring the theoretical references, a brief description of the methodological procedures, data presentation and analysis and the research results, our considerations about the data, and the conclusions of the investigation.

## **THEORETICAL FRAMEWORK**

In this section, we briefly present some theoretical frameworks that we assume for the development of the investigation. Among the topics we address are our thoughts on the role of human and non-human actors (the media) in the process of knowledge production, what we believe action is, and what we think of the incorporation of digital technologies in our mathematics teaching and learning. With this, we want to elucidate the goal, that is, to highlight the teachers' and students' actions, their categorisations, and connections during the implementation of mathematics classes planned with the use of a LO on a DB.

Nowadays, humanity “[...] is immersed in a methodological basis sustained by cyber-physical systems, supported by the internet and cloud computing” (Kalinke & Motta, 2019, p. 11). The authors also state that “[...] the individual lives for the collective, sharing knowledge in real-time, permeated by the DT” (p. 11).

Even experiencing the changes that digital technologies impose on our lives, we are still rooted in the culture of a classroom that does not allow or resist access to the internet. In this culture, the teachers’ role is, in a very conservative view, considered central in the knowledge production process (Borba, 2012). As students, most of the time we turn to the teacher to solve doubts or to legitimise our conjectures. (Souto & Borba, 2016, p. 219)

However, the internet advances at an exponential speed, gaining space in education, mainly in the classroom. In this way, it destabilises some of our beliefs, as it causes changes in socially agreed rules related to the roles that each actor can or should play in the knowledge production process (Souto & Borba, 2016). Still, Souto and Barbosa (2016) argue that the culture of today’s society features configurations and reconfigurations of different theoretical perspectives, “[...] which suggest that the human actor should not be seen as the only one, nor the main responsible for the knowledge produced, there is an emphasis on the collectivity with the co-participation of non-humans in this process” (Souto & Borba, 2016, p. 219).

Some studies in mathematics education developed in virtual classrooms discuss, among other issues, the role of non-human actors (media) in the process of mathematical production in this context (e.g., Gracias, 2003; Borba & Villarreal, 2005; Santos, 2006; Zulatto, 2007; Malheiros, 2008; Rosa & Maltempi, 2010; Borba, Malheiros & Amaral, 2011; Villarreal & Borba, 2010). The results of these studies suggest that the media are also necessary for producing mathematical knowledge. (Souto & Borba, 2016, p. 219)

In our research, we gave priority to providing students with learning environments using DTs and other media, establishing a collective of human-beings-with-media, with the main actors being: a digital board (DB) and a learning object (LO); students organised into teams, interacting with each other and with the research professor to explore the following mathematical concepts: fractions, equivalent fractions, mixed numbers, decimal numbers,

proportional quantities, equations, area, fractional areas, perimeter and scale; situations in which they could elaborate and test conjectures and produce mathematical ideas related to the topic.

According to Souto and Borba (2016), the construct of human-beings-with-media is based on the idea that knowledge is produced by thinking collectives of human and non-human actors, in which everyone plays a central role. According to Borba and Villarreal (2005 apud Souto & Borba, 2016, p. 222), “[...] there is also no quality scale between the media that can classify them as better or worse, but different types that have, throughout history, conditioned the production of different types of knowledge”.

When individuals interact with the media, they reorganise their thinking according to the various possibilities and restrictions they provide (Souto & Borba, 2016). The authors also state that:

[...] their presence or absence influences the type of knowledge produced, and the use or the emergence of a particular medium does not invalidate or extinguish another, although it often places it in a different position from the one it occupied previously. (Souto & Borba, 2016, p. 222)

It should be noted that the expression human-beings-with-media has its origin in Borba (2001), although there are registers that indicate that it permeates the propositions of a system formed by human-computer beings (Tikhomirov, 1981) and by the collective intelligence man-things (Lévy, 1993).

We understand that, in this construct, the idea of mediation extends to one of mutual impregnation, where the media permeate the human just like the technologies are understood to be impregnated with humanity. (Souto & Borba, 2016, p. 222)

Finally, we bring what we have assumed by action. According to the first vignettes in the Houaiss dictionary (Houaiss, Villar & Franco, 2009), action is an “act of acting”, a “dynamic process in which there is an agent doing something”, a “way of proceeding”. According to this definition, in recent research (Vicentin, Passos & Arruda, 2019, 2020), action has been considered the focus of an investigative movement that seeks to study both the teaching action (the teacher’s actions in class aiming at teaching and learning), and the students’ action (students’ activity in class to learn school knowledge).

Both teaching actions and students' actions are described by verbs, as we can see by looking at Tables 2 and 31 in the Results and Discussions section, to characterise the teacher's and students' actions in classroom situations while exploring a LO, in other words, in classes that use technologies.

Regarding the class preparation that includes digital technologies (a DB and a LO) in planning and development, we elucidate that we seek inspiration from Silva (2015) when he indicates several methodological trends in mathematics education that can be used in mathematics the teaching and learning processes. In this article, we emphasise the incorporation of the DTs for mathematics teaching and learning, as we agree with this author's understanding that the use of information and communication technologies (ICT) integrated into teaching practices "[...] provide students with tools that allow them to meet present and future technological demands" (Silva, 2015, p. 12).

After a short delimitation of what we understand of some concepts, definitions, and fundamental concepts for the development of this investigation, we will describe the methodological procedures adopted in the research.

## **METHODOLOGY**

The school where we implemented and analysed the mathematics classes was from the Paraná state network. We collected data from two elementary school classes (6<sup>th</sup> grade, with ten students; 7<sup>th</sup> grade, with 14 students) and a 3<sup>rd</sup>-grade high school class, with 12 students. The eight classes, lasting 50 minutes each, were developed in the multipurpose room.

The class teacher has also been engaged in researching and understanding the use of the digital board. The DB was initially placed as the central piece of an investigative movement, part of a research programme that has been studying teachers' and students' actions in mathematics teaching and learning since 2014.

To maintain the secrecy and anonymity of the subjects involved in the process, we assigned codes to the participants and suppressed the school's

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<sup>1</sup>It is evident that not all teacher's actions are directly related to teaching and not all students' actions directly intend to the act of learning, a fact evidenced in this article.

name. The students and their guardians were aware of their participation in the research, and the school was registered on Plataforma Brasil.<sup>2</sup>

As we aimed to categorise the teacher's and students' actions and their possible connections, the classes were recorded by two cameras in different positions: one focused on the teacher and the other on the teams of students while carrying out the activities. Also, we made registers through field notes, complementing the data captured by the two cameras.

Our method of analysis was based on the CA procedures as conceived by Moraes (1999) in the interpretation of data to characterise the actions of the investigated subjects (students and teacher), because “[...] it allows us to meet the innumerable needs of researchers involved in the analysis of communication data, especially those focused on a qualitative approach” (Moraes, 1999, p. 30). As for the qualitative research, the methodological approach we adopted in this investigation, according to Flick (2009, p. 25), “[...] considers the researcher's communication in the field as an explicit part of the production of knowledge”. We also emphasise that “[...] in a way, the CA is a personal interpretation on the part of the researcher regarding the perception they have of the data. Neutral reading is not possible” (Moraes, 1999, p.24).

To organise all the information regarding students' and teacher's actions –the transcript of the classes and the field notes– we created tables with five columns that accommodate, from left to right, the following descriptions: transcription of the most representative speeches of the teacher; teacher's actions (teaching action subcategories); transcription of the most representative speeches of the students; students' actions (students' action subcategories); connections between teacher's and students' actions. In Table 1, we insert the header of this organisation. We also explain that we did not insert examples of the data interpreted and accommodated in the columns because they are in the descriptions of the following tables and because we need an expressive number of registers to help readers understand the classes imparted.

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<sup>2</sup> For the Ethics Committee, the project is identified as follows – CAAE: 57663716.9.0000.5231 e Parecer: 1.666.360.

**Table 1***Example of data organisation*

| Transcripts of the most representative speeches of the teacher | Teacher's action subcategories | Transcripts of the most representative speeches of the students | Students' action subcategories | Connections between actions |          |
|--|--------------------------------|---|--------------------------------|-----------------------------|----------|
|  |                                |   |                                | Teacher                     | Students |

Before presenting the categories of teacher's action and the comments related to our findings, exposed later in Table 2, we clarify that the categories of the teacher's action were elaborated from the data organisational process. In the first movement, we transcribed what the teacher said, fragmenting each speech depending on an action performed by him. Let us see two examples: *How many kilograms are on this side of the scale? What operation should you do to find the answer?* In these two cases, the teacher's action was identified by the verb – Ask – and is related to two subcategories: Ask students about the LO activity, and ask students about the LO contents, respectively. It is also worth clarifying that some of the teacher's actions were silent and, therefore, we always registered them in column 2 (as explained in the header of Table 1). This allowed us to complete columns 1 and 2 of Table 1.

In the second movement, we transcribed students' and teacher's speeches, identifying and naming their actions. We insert two examples that illustrate what we do: *The bucket has twenty kilograms of mass (A1). It is fifteen because the distance is double, so the mass is half of thirty (A4).* In these cases, students' action in the first transcript is Discover, and in the second, it is Discuss. The subcategories of both students' actions (occurring in classes 7 and 8) were: They discover the mass of the objects; They discuss possible solutions with the teacher and the other students, respectively. Transcription and interpretation are presented in columns 3 and 4, indicated in Table 1.

Finally, in the third movement, we insert the analysis results in the fifth column of Table 1, which brings indications for the teacher and the students (since it was subdivided). We also bring an example that occurred at the beginning of classes 7 and 8. When the teacher asks, let us see the transcript of his speeches: *Which pair will start the activity? How many kilograms are on this side of the scale? Do you now understand how to find out the mass of the object? Which side of the scale has more mass? What about now? What will be the mass of the bucket? Did you find out?* Students



perform several actions: erase; drag; assist; search; check; discover; draw; discuss; write; speak; indicate; start; justify; watch; realise; pay attention; perform; answer; select; requests assistance (Apaga; Arrasta; Auxilia; Busca; Confere; Descobre; Desenha; Discute; Escreve; Fala; Indica; Inicia; Justifica; Observa; Percebe; Presta atenção; Realiza; Responde; Selecciona; Solicita auxílio - registered in Portuguese in alphabetical order).

## RESULTS AND DISCUSSION

From the investigative movement, we developed 22 categories for the teacher's actions and 40 categories for the students' actions, which are listed and described in Tables 2 and 3, respectively. To name those categories – which represent actions, according to our conceptions–, we use verbs.

In Table 2, we insert all the verbs that represent the actions performed by the teacher for the analysed classes –column 1– and the description of what we assume for each of the categories –column 2.

**Table 2**

*Categories of teacher's actions for the analysed classes*

| Categories of teacher's actions | Category descriptions  |
|---------------------------------|--|
| 1. Assist                       | This category reveals that the teacher helps students in: the activity and contents of the LO; simulation strategies; the techniques of mental calculation; the use of the LO; how to drag objects with the digital pen; using the digital pen in 'interactive' mode; using the ultrabook mouse.   |
| 2. Calibrate                    | The 'Calibrate' category is related to the technical procedure of calibrating the DB, an essential action for the proper functioning of the digital pen, and explaining and answering students' questions about the DB calibration during the action.  |
| 3. Comment                      | This category refers to making different comments to students, such as on the contents of the activity; how the evaluation will take place; how to carry out the tasks; how students are organised (in teams) to carry out the activity; the number of tasks that each team will perform; who will assist the teams in carrying out the activity; that they will be able to assist and request assistance from other students and the teacher. |
| 4. Coordinate                   | This category is related to the teacher led the teams during the activity.   |
| 5. Demonstrate                  | The action of demonstrating involves several subactions. Demonstrate to students how to drag objects with the digital pen and the ultrabook mouse; carry out the LO activity; explore the LO with the digital pen and the ultrabook mouse; simulate; calibrate the DB, and use the digital pen.  |
| 6. Discuss                      | This category includes the discussion with the students regarding the possible resolution strategies for the LO activity; the possible solutions to the questions of the LO activity; simulation strategies for the activity questions.  |

7. Hand out      Handing out is related to the supply of printed materials to the students containing the tasks to be answered during the performance of the LO activity.
8. Wait            The waiting action involves several sub-actions, such as waiting for students: to carry out the LO activity; answer your questions about the activity and contents of the LO. It also refers to the teacher's action of waiting for a connection between the equipment (projector, DB receiver, and ultrabook), concerning technical issues.
9. Explain        The 'Explain' category is represented by explaining to students: how to drag objects with the digital pen and with the ultrabook mouse; the number of tasks that each team must perform; the activity and contents of the LO; mental calculation techniques; the existence of different levels of difficulty for the LO activity; how to use the LO with the digital pen and with the ultrabook mouse; the possible simulations to be carried out through the LO; why it was not possible to drag objects with the digital pen in 'interactive' mode; the LO activity; the DB, and the functioning of the digital pen.
10. Expose        This category highlights the moments the teacher exposes to the students which contents will be studied during the LO activity and the different levels of difficulty of the LO.
11. Encourage    The 'Encourage' category involves several subactions, such as encouraging students to help team partners and other students in carrying out the LO activity; seek different resolution strategies for the LO activity; carry out the LO activity.
12. Indicate      The indicate action is constituted of the actions of indicating: the mistake made by the team partners and the other students during the accomplishment of the LO activity; possible resolution strategies for the LO activity tasks; different possibilities of simulations.
13. Turn on        This category is related to the technical procedure of connecting the equipment (projector, DB receiver and ultrabook).
14. Ask            The 'Ask' category involves several subactions, such as asking students about the LO activity and contents; the solution of the tasks (questions) of the LO activity; which team will start carrying out the LO activity; which will be the next team to carry out the LO activity.
15. Pay attention    This action is composed of the secondary actions of paying attention to: the different strategies used by the students in solving the LO activity through the projection of the DB; the students, while they carry out the LO activity through the DB projection; the simulations carried out by the students through the projection of the DB.
16. Project        A category that refers to the technical procedure of projecting the LO using the DB.
17. Carry out      This category is related to carrying out the action of calling the roll, a common practice in formal education as a mandatory bureaucratic practice.
18. Solve          The 'Solve' category refers to the teacher's action to solve technical problems that occurred with: the digital pen –one of the physical components of DB– in the 'interactive' mode, not being possible to use the 'check' button or drag objects with the digital pen; the connection of equipment (projector, DB receiver, and ultrabook), necessary action due to the interruption of the projection of the LO, preventing the activity from being carried out.
19. Answer        The 'Answer' category involves several sub-actions —answer students' questions about: the LO, the LO activity, and contents.
20. Request        Category in which the teacher asks students to: help teammates and other students in carrying out the activity and in the LO contents; be silent; pay attention to the LO activity; get organised into teams, and that the team starts the LO activity; check the answer to the LO questions; perform the calculation to answer the tasks related to each LO activity.
21. Suggest        This action is attributed to several subactions, such as suggesting that students calculate to solve the LO activity; possible resolution strategies for the LO

- activity; that they change their strategy while carrying out the LO activity; to perform the calculation before risking an answer to the LO activity; how to start the LO activity; possible simulations.
22. Value The category 'Value' expresses, implicitly or explicitly, the appreciation of students' participation; an action that came from the spontaneous initiative of the teacher and was an indispensable attitude to maintain the students' interest in the LO activity during all classes.
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In Table 3, we insert the categories of students' actions (actions performed during the analysed classes), accommodated in column 1, and the description of each of those categories, accommodated in column 2. As in the case of the analysis related to the teacher, we reinforce that there were students' silent actions, so they were recorded only in column 4 of Table 1 (explained in the previous section). We also emphasise that for this operation, we had to revisit the videos and registers of the field notebook numerous times.

**Table 3**

*Categories of students' actions for the analysed classes*

| Categories of students' actions | Category descriptions  |
|---------------------------------|--|
| 1. Accepted or not              | This action is attributed to several subactions, such as accepting or not the suggestions of the other students and the teacher regarding: the resolution of the LO activity; the resolution strategies for the LO activity and its changes during its performance; the answers to the LO activity questions; performing calculations necessary to the resolution of the LO activity; the way to start the LO activity.        |
| 2. Erase                        | Category that refers to the action of erasing the registers they made on the blackboard.   |
| 3. Drag                         | Category related to the action of dragging objects with the digital pen and the ultrabook mouse.   |
| 4. Risk                         | This category is related to the action of risking an answer to a LO activity.  |
| 5. Check                        | The category 'check' is related to the action of checking the answer to the questions in the activity.   |
| 6. Assist                       | This category involves several subactions, such as helping other students in: the LO activity; the contents of the LO activity; the use of the digital pen, the search for strategies to solve the LO activity; the search for resolution strategies and simulations. Moreover, helping the teacher in solving technical problems with the digital pen; when turning on the equipment (projector, DB receiver, and ultrabook). |
| 7. Search                       | This category refers solely to the students' action in seeking resolution strategies for the LO activity.  |
| 8. Celebrate                    | The 'Celebrate' category is related to the moments in which the students practice the action of celebrating the successes by correctly solving the LO activity.  |
| 9. Check                        | The 'Check' category refers to the students' action to check the response of the LO activity with the digital pen and with the ultrabook mouse.  |
| 10. Discover                    | Action referring to the students' discovery of the mass of the objects.  |

11. Draw This category is related to the action of drawing on the blackboard, which helped the students solve the activities.
12. Discuss The action of discussing is composed of the secondary actions of discussing with other students some likely resolution strategies for the LO activity; solutions for the LO activity; resolution strategies for the LO activity; simulation strategies, strategies for using the simulator (LO) and answers to the questions of the LO activity. The other secondary actions of discussing with the teacher possible resolution strategies for the LO activity; solutions for the OA activity; simulation strategies and answers to the OA activity questions.
13. Write Category exclusively related to the action of writing on the blackboard that assist students in solving activities.
14. Listen The 'Listen' category involves several subactions, such as listening to the teacher comment that the LO activity will be carried out in teams; who will assist the teams in carrying out the LO activity; the number of tasks of the LO activity to be carried out; that they can help and ask for help from other students and from him; the way they will be evaluated during the execution of the LO activity; the contents to be studied through the LO activity; when exposing the contents to be studied through the LO activity; when exposing about the different levels of difficulty of the LO. Also, it refers to the action of listening to music with a mobile phone headset.
15. Wait Category associated with the action of waiting for the teacher to: calibrate the DB; turn on the equipment (projector, DB receiver, and ultrabook); connect the equipment (projector, DB receiver, and ultrabook) and solve technical problems during the connection of equipment (projector, DB receiver, and ultrabook) and with the digital pen.
16. Explain Action related to several student subactions. Explain to other students how to use the simulator (LO) with the digital pen and with the ultrabook mouse; simulations possible to be carried out through the simulator (LO); about the LO activity; possible strategies of resolution for the questions of the activity; about the simulations; about the contents of the LO activity.
17. Speak The category 'Speak' refers to the students' action of talking to other students: the answer to the LO activity; that his/her LO activity resolution strategy is correct; that they did not understand the question of the activity. It also involves the action of telling the teacher that: they liked the simulator (LO); they are not good at calculations; it is difficult to find the mass of the object; they understood how to resolve the question proposed by the LO.
18. Encourage The 'Encourage' category is related to the action of encouraging the pair partner and the other students: to seek different resolution strategies for the LO activity and to carry out the LO activity.
19. Indicate This category encompasses the action of telling the mistake made to other students in the LO activity.
20. Start The 'Start' category refers to the students' action of beginning the LO activity and the activity to be performed with the simulator (LO).
21. Justify Category related to the action of justifying the answer given to the teacher.
22. Read This category comprises the action of reading the activity questions.
23. Use Category that depicts the action of using the cell phone.
24. Observe This action is attributed to several subactions, such as observing: the simulator (LO) and the LO activity through the DB projection area and the ultrabook; the other students carry out the LO activity and carry out the activity with the simulator (LO); the teacher to calibrate the DB.
25. Organise This category is related to the students' action to get organised into teams.
26. Participate This category is related to the participation in carrying out the LO activity and of the activity using the simulator (LO).
27. Realise Action that leads students to understand how to discover the mass of objects.
28. Ask The 'ask' category involves several subactions, such as asking the teacher: what

|                         |  |
|-------------------------|--|
|                         | contents will be studied by carrying out the LO activity; whether they can carry out the activity in teams of three; whether calculations can be performed on the blackboard; about the LO activity; about the contents of the LO; about DB calibration; about the order in which the teams will carry out the activity; about the number of tasks of the LO activity each pair will have to perform; about possible strategies to be used in the simulator (LO); about the simulator (LO). It also refers to the subactions of asking other students: about the LO activity; about the contents of the LO; whether they agree with the answers to the activity questions.   |
| 29. Pay attention       | The 'Pay attention' category involves several subactions, described below: they pay attention to the LO activity and the simulator (LO) through the DB projection area and the ultrabook; pay attention to the teacher's requests; pay attention to the teacher's explanation about the activity to be carried out through the simulator (LO), the LO activity, the LO contents, the DB calibration, the existence of different levels of difficulty for the LO activity, how to drag objects with the digital pen, how to use the simulator (LO) with the ultrabook mouse and with the digital pen, the DB, the number tasks that each pair will perform from the LO activity, the operation of the digital pen, possible simulations to be carried out through the simulator (LO), mental calculation techniques; pay attention to the teacher when he/she is demonstrating how to drag objects with the digital pen and with the ultrabook mouse, carry out the LO activity, proceed with the DB calibration, perform the LO activity, use the digital pen, use the simulator (LO) with the digital pen and with the ultrabook mouse, and also to present possible simulations to be performed with the simulator (LO). |
| 30. Carry out           | This category involves the following subactions: perform the LO activity and simulations through the LO with the ultrabook mouse and with the digital pen; and perform calculations mentally and by recording on the blackboard.   |
| 31. Receive             | Category linked solely to the action of receiving the printed activity to be carried out.  |
| 32. Register            | Category associated with the students' action in registering the contents of the LO activity in the notebook during the teacher's explanations.  |
| 33. Answer              | The 'Answer' category is constituted by the actions of answering to: other students' questions about the activity and contents of the LO; the roll call; the teacher's questions about the solution of the LO activity; the teacher the reason for not having answered the question correctly and that they understood how to perform the calculation to find the solution.  |
| 34. Select              | This action is composed of the secondary actions of selecting: the activity of the LO with the digital pen and with the ultrabook mouse; the answer to a LO activity with the digital pen; the answer to the LO activity with the digital pen and with the mouse of the ultrabook; the level of difficulty of the LO activity with the digital pen and with the mouse of the ultrabook; the LO activity with the digital pen and with the mouse of the ultrabook.  |
| 35. Feel interested     | Action referring to feeling interested in the objects and figures of the LOs, and the activity of the LO.  |
| 36. Request assistance  | The 'Request assistance' category encompasses the subactions of requesting assistance from other students and the teacher on: the activity and contents of the LO; the simulator (LO); the possible strategies to be used in the simulator (LO).   |
| 37. Request explanation | Action associated with the request for an explanation to the teacher about the activities and contents of the LOs and the functioning of the digital pen.  |
| 38. Suggest             | The 'Suggest' action involves two other subactions: they suggest to the other students' resolution strategies for the LO activity and they suggest to the teacher other technologies for the use of the simulator (LO).  |
| 39. Take                | Category that refers exclusively to the action of taking selfies.  |
| 40. Use                 | The 'Use' category is solely related to the students' action of using different  |

From now on, our attention turns to column 5 of Table 1, presented in the previous section. The result of the data organisation, already interpreted in this column, allowed us to create Table 4, inserted in the sequence. We highlight, in Table 4, the connections between the teacher's and the students' actions and the quantification of categories referring to their actions.

Table 4 brings the analytical results of classes in which three LOs were applied: Swinging for the 6<sup>th</sup> grade of elementary school (column 1); Area builder for the 7<sup>th</sup> grade of elementary school (column 2); and Resistance in a wire for the 3<sup>rd</sup> grade of high school (column 3). We emphasise that each column was subdivided into two (accommodating the teacher's and the students' actions, respectively).

We ask the reader to pay attention to the number of categories after the verb that characterises the action —in the first subdivision of column 1 in its first line, we have Assist (1) — which indicates a category of a teacher's action. In this same line (the first), and in the second subdivision of the same column (the first), we have a list of verbs related to students' actions in connection with this teacher's action —in parentheses at the end of the list (11) — which quantifies eleven students' actions related to the teacher's action 'Assist'.

**Table 4**

*Connections between the teacher's and the students' actions in the analysed classes*

| LO Swinging<br>6 <sup>th</sup> grade of elementary<br>school |  | LO Area Builder<br>7 <sup>th</sup> grade of elementary school |  | LO Resistance in a wire<br>3 <sup>rd</sup> grade of high school |  |
|--|--|---|--|---|--|
| Teacher  | Students   | Teacher   | Students   | Teacher   | Students   |
| Assist<br>(1)  | Erase, Drag,<br>Assist, Check,<br>Draw, Write,<br>Observe, Pay<br>attention,<br>Carry out,<br>Select,<br>Request<br>assistance<br>(11) | Assist<br>(1)   | Delete, Drag,<br>Risk, Assist,<br>Celebrate,<br>Check, Draw,<br>Encourage,<br>Start, Observe,<br>Ask, Pays<br>Attention,<br>Carry out,<br>Answer, Select,<br>Request | Assist<br>(1)   | Accept or not,<br>Tick, Assist,<br>Discuss,<br>Explain, Read,<br>Observe, Ask,<br>Pay attention,<br>Carry out,<br>Answer,<br>Request<br>assistance<br>(12) |

|                    |   |                    |   |                    |   |
|--------------------|---|--------------------|---|--------------------|---|
|                    |   |                    | Assistance, Use<br>(17)   |                    |   |
| Calibrate<br>(1)   | Wait, Observe,<br>Ask, Pay<br>Attention<br>(4)  | Calibrate<br>(1)   | Wait, Observe<br>(2)  | Calibrate<br>(1)   | Wait, Observe<br>(2)  |
| Comment<br>(1)     | Listen<br>(1)   | Comment<br>(1)     | Listen<br>(1)   | Comment<br>(1)     | Listen, Ask<br>(2)  |
| Coordinate<br>(1)  | -----   | Coordinate<br>(1)  | -----   | Coordinate<br>(1)  | -----   |
| Demonstrate<br>(1) | Pay attention<br>(1)  | Demonstrate<br>(1) | Pay attention<br>(1)  | Demonstrate<br>(1) | Pay attention<br>(1)  |
| Discuss<br>(1)     | Discuss<br>(1)  | Discuss<br>(1)     | Discuss<br>(1)  | Discuss<br>(1)     | Discuss<br>(1)  |
| -----              | -----   | -----              | -----   | Hand out<br>(1)    | Receive<br>(1)  |
| Wait<br>(1)        | Erase, Drag,<br>Assist, Check,<br>Draw, Write,<br>Wait, Observe,<br>Pay attention,<br>Carry out,<br>Answer, Select<br>(12)  | Wait<br>(1)        | Erase, Drag,<br>Risk, Assist,<br>Celebrate,<br>Check, Draw,<br>Encourage,<br>Start, Observe,<br>Pay Attention,<br>Carry out,<br>Answer, Select,<br>Use<br>(15)  | Wait<br>(1)        | Accept or not,<br>Tick,<br>Assist,<br>Discuss, Wait<br>Explain, Read,<br>Observe, Ask,<br>Pay Attention,<br>Carry out,<br>Answer,<br>Request<br>assistance<br>(13)                            |
| Explain<br>(1)     | Erase, Drag,<br>Assist, Check,<br>Draw, Write,<br>Observe, Pay<br>attention,<br>Carry out,<br>Select,<br>Request<br>assistance,<br>Request<br>explanation<br>(12) | Explain<br>(1)     | Erase, Drag,<br>Risk, Assist,<br>Celebrate,<br>Check, Draw,<br>Encourage,<br>Indicate, Start,<br>Observe, Ask,<br>Pay Attention,<br>Carry out,<br>Answer, Select,<br>Request<br>Assistance,<br>Request<br>explanation,<br>Use<br>(19) | Explain<br>(1)     | Accept or not,<br>Tick, Assist,<br>Discuss,<br>Explain,<br>Speak, Read,<br>Observe, Ask,<br>Pay attention,<br>Carry out,<br>Register,<br>Answer,<br>Request<br>assistance,<br>Suggest<br>(15) |
| Expose<br>(1)      | Listen<br>(1)   | Expose<br>(1)      | Listen, Ask<br>(2)  | Expose<br>(1)      | Listen<br>(1)   |
| Encourage<br>(1)   | Erase, Drag,<br>Assist, Check,<br>Draw, Write,<br>Observe, Pay<br>attention,<br>Carry out,<br>Select,<br>Request  | Encourage<br>(1)   | Erase, Drag,<br>Risk, Assist,<br>Celebrate,<br>Check, Draw,<br>Encourage,<br>Start, Observe,<br>Pay Attention,<br>Carry out,  | Encourage<br>(1)   | Accept or not,<br>Tick, Assist,<br>Discuss,<br>Explain, Read,<br>Observe, Ask,<br>Pay attention,<br>Carry out,<br>Answer,   |

|                      |  |                      |   |                         |  |
|----------------------|--|----------------------|---|-------------------------|--|
|                      | assistance<br>(11)   |                      | Select, Request<br>Assistance, Use<br>(15)  |                         | Request<br>assistance<br>(12)  |
| Indicate<br>(1)      | Accept or not,<br>Erase, Drag,<br>Assist, Search,<br>Check, Draw,<br>Write,<br>Observe, Pay<br>attention,<br>Carry out,<br>Select<br>(12)  | Indicate<br>(1)      | Accept or not,<br>Erase, Drag,<br>Risk, Assist,<br>Celebrate,<br>Check, Draw,<br>Encourage,<br>Indicate, Start,<br>Observe, Pay<br>Attention,<br>Carry out,<br>Select, Use<br>(16)  | Indicate<br>(1)         | Accept or not,<br>Tick, Assist,<br>Discuss,<br>Explain, Read,<br>Observe, Ask,<br>Pay attention,<br>Carry out,<br>Answer<br>(11)                           |
| Turn on<br>(1)       | Wait<br>(1)  | Turn on<br>(1)       | Wait<br>(1)   | Turn on<br>(1)          | Assist, Wait<br>(2)  |
| Ask<br>(1)           | Erase, Drag,<br>Assist, Search,<br>Check,<br>Discover,<br>Draw, Discuss,<br>Write, Speak,<br>Indicate, Start,<br>Justify,<br>Observe,<br>Notice, Pay<br>attention,<br>Carry out,<br>Answer,<br>Select,<br>Request assist<br>(20) | Ask<br>(1)           | Erase, Drag,<br>Risk, Assist,<br>Celebrate,<br>Check, Draw,<br>Discuss, Speak,<br>Encourage,<br>Indicate, Start,<br>Justify,<br>Observe, Pay<br>Attention,<br>Carry out,<br>Answer, Select,<br>Request<br>Assistance, Use<br>(20) | Ask<br>(1)              | Accept or not,<br>Tick, Assist,<br>Discuss,<br>Explain, Read,<br>Observe, Ask,<br>Pay attention,<br>Carry out,<br>Answer,<br>Request<br>assistance<br>(12) |
| Pay attention<br>(1) | Erase, Drag,<br>Assist, Search,<br>Check, Draw,<br>Write,<br>Observe, Pay<br>attention,<br>Carry out,<br>Select, Use<br>(12)   | Pay attention<br>(1) | Erase, Drag,<br>Risk, Assist,<br>Celebrate,<br>Check, Draw,<br>Discuss,<br>Encourage,<br>Start, Observe,<br>Pay Attention,<br>Carry out,<br>Select, Use<br>(15)   | Pay<br>attention<br>(1) | Accept or not,<br>Tick, Assist,<br>Discuss,<br>Explain, Read,<br>Observe, Ask,<br>Pay attention,<br>Carry out,<br>Answer<br>(11)                           |
| Project<br>(1)       | Observe<br>(1)   | Project<br>(1)       | Observe<br>(1)  | Project<br>(1)          | Observe<br>(1)   |
| Carry out<br>(1)     | Answer<br>(1)  | Carry out<br>(1)     | Answer<br>(1)   | Carry out<br>(1)        | Answer<br>(1)  |
| Solve<br>(1)         | Assist, Wait<br>(2)  | Solve<br>(1)         | Wait<br>(1)   | -----                   | -----  |
| Answer<br>(1)        | Ask<br>(1)   | Answer<br>(1)        | Ask<br>(1)  | Answer<br>(1)           | Ask<br>(1)   |
| Request<br>(1)       | Erase, Drag,<br>Assist, Check,<br>Draw, Write,   | Request<br>(1)       | Erase, Drag,<br>Risk, Assist,<br>Celebrate,   | Request<br>(1)          | Accept or not,<br>Tick, Assist,<br>Discuss,  |



|                |  |                |  |                |  |
|----------------|--|----------------|--|----------------|--|
|                | Start, Observe,<br>Organise, Pay<br>attention,<br>Carry out,<br>Answer,<br>Select,<br>Request<br>assistance<br>(14)  |                | Check, Draw,<br>Encourage,<br>Indicate, Start,<br>Observe,<br>Organise, Pay<br>Attention,<br>Carry out,<br>Answer, Select,<br>Request<br>Assistance, Use<br>(18)   |                | Explain, Start,<br>Read,<br>Observe,<br>Organise, Ask,<br>Pay attention,<br>Carry out,<br>Answer,<br>Request<br>assistance<br>(14)                         |
| Suggest<br>(1) | Accept or not,<br>Erase,<br>Drag, Risk,<br>Assist, Search,<br>Check, Draw,<br>Discuss, Write,<br>Observe, Pay<br>attention,<br>Carry out,<br>Select, Suggest<br>(15) | Suggest<br>(1) | Accept or not,<br>Erase, Drag,<br>Risk, Assist,<br>Celebrate,<br>Check, Draw,<br>Discuss,<br>Encourage,<br>Indicate, Start,<br>Observe, Pay<br>Attention,<br>Carry out,<br>Select, Suggest,<br>Use<br>(18) | Suggest<br>(1) | Accept or not,<br>Tick, Assist,<br>Discuss,<br>Explain, Read,<br>Observe, Ask,<br>Pay attention,<br>Carry out,<br>Answer,<br>Request<br>assistance<br>(12) |
| Value<br>(1)   | Celebrate,<br>Participate<br>(2)   | Value<br>(1)   | Celebrate,<br>Participate<br>(2)   | Value<br>(1)   | Participate<br>(1)   |
| -----          | Deal with,<br>Feel<br>Interested,<br>Take<br>(3)   | -----          | Deal with, Feel<br>interested<br>(2)   | -----          | Deal with,<br>Feel interested<br>(2)   |

We could see in the registers accommodated in Table 4 that some of the teacher's actions are integrally connected with the students' actions. We list some examples below: the teacher comments and the students listen (line 3); while the teacher makes several demonstrations, the students pay attention (line 5); while the teacher proposes discussions, the students carry out the same action (line 6); when the teacher hands out the activity to be carried out, the students receive it (line 7); while the teacher exposes, the students listen (line 10); while the teacher turns on the equipment, the students wait for the completion of this action (line 13); the teacher projects the LO and the students observe (line 16); at the same time the teacher call the roll, the students only answer (line 17); when the teacher solves several technical problems that have occurred, the students practice the action of waiting (line 18); the teacher answers due to the asking action carried out by the students

(line 19); as a consequence of the teacher's action of valuing students in the course of carrying out the proposed activities, students participate in classes with more commitment (line 22).

However, it was also evident that there were actions of the teacher – Assist, Calibrate, Wait, Explain, Encourage, Indicate, Ask, Pay attention, Request, Suggest– that triggered several other students' actions, as can be resumed in lines 1, 2, 8, 9, 11, 12, 14, 15, 20, and 21 of Table 4. In other words, for a set of teacher's actions, there is usually always a triggering of corresponding students' actions.

Furthermore, we highlight the interpreted data, stating that three categories of students' actions were identified – 'Deal with', 'Feel Interested' and 'Take' (line 23, last line of Table 4) – that do not interrelate with the teacher's actions. We can consider that during the analytical process carried out, the actions in these categories are not directly linked with the execution of the LO activity. However, they were provided by the learning environment in which the students used technological resources and emerged due to students' interest in using the mobile and objects and figures of the LOs and the activity proposed. We also clarify that these students' actions highlighted in this paragraph did not seem to have arisen due to the teacher's action.

Lastly, we should remark that during the entire analytical process, the category of teaching action 'Coordinate' (line 4 of Table 4), related to how the teacher led the teams during the execution of the activities, was the only teaching action that did not incite students to act.

We finished this section by comparing the teacher's and students' actions in previous investigations with those we identified in this research (Table 5), in which mathematics classes were planned and implemented through different approaches. This movement allowed us to notice the similarities and differences between the teacher's and students' actions in the different methodological approaches, as can be seen in columns 2 and 3 of Table 5.

The first column of Table 5 brings the types of planning used by the researchers/authors of the analysed documents; the second column, the list of teacher's actions identified, and, at the bottom of the list, the number of categories elaborated; and the third column, the categories of students' actions (when they exist) and quantification.

**Table 5**

*Similarities and differences between categories in mathematics classes*  
(Andrade & Arruda, 2017; Dias, 2018; Dias, Arruda & Passos, 2020)

| Types of planning   | Categories of teachers' actions   | Categories of teachers' actions  |
|---|---|--|
| Traditional<br>(Andrade & Arruda, 2017)                           | Bureaucratic-administrative, Write, <b>Wait</b> , <b>Explain</b> – 4 categories.  | Not yet been researched.   |
| Use of games<br>(Dias, 2018)                                      | Thank, Threaten, Argue, Scold, <b>Comment</b> , Check, Move, Write, <b>Wait</b> , Execute, <b>Explain</b> , Negotiate, Organise, Congratulate, Request, <b>Ask</b> , Provide, <b>Answer</b> – 18 categories.  | Not yet been researched.   |
| The use of manipulable materials<br>(Dias, Arruda & Passos, 2020) | Threaten, Argue, Scold, Move, Write, <b>Wait</b> , <b>Explain</b> , Organise, Request, <b>Ask</b> , Provide, Disapprove, <b>Answer</b> , Supervise – 14 categories.   | Play, Call the teacher, Collaborate, Comment, Communicate, Chat, Copy, Move, Execute, Request, <b>Ask</b> , Complain, <b>Answer</b> , Value – 14 categories.   |
| Exploration of learning objects                                   | Assist, Calibrate, <b>Comment</b> , Coordinate, Demonstrate, Discuss, Hand out <b>Wait</b> , <b>Explain</b> , Expose, Encourage, Indicate, Turn on, <b>Ask</b> , Pay attention, Project, Carry out, Solve, <b>Answer</b> , Request, Suggest, Value – 22 categories. | Accept or not, Erase, Drag, Risk, Tick, Assist, Search, Celebrate, Check, Discover, Draw, Discuss, Write, Listen, Wait, Explain, Speak, Encourage, Indicate, Start, Justify, Read, Deal with, Observe, Organise, Participate, Realise, <b>Ask</b> , Pay attention, Carry out, Receive, Register, <b>Answer</b> , Select, Feel Interested, Request assistance, Request explanation, Suggest, Take, Use – 40 categories. |

The analysis of the categories compiled in Table 5 allows us to verify that the teaching actions ‘Wait’ and ‘Explain’ are present in classes with different approaches (traditional, use of games, use of manipulative materials, and exploration of learning objects).

The ‘Ask’ and ‘Answer’ teaching action categories were identified in planned classes through the exploration of learning objects, manipulative materials, and games.

Regarding the ‘Comment’ category of teacher’s action, we noticed it occurred in classes in which learning objects were explored and in those whose approach was using games.

The action of calling the roll was categorised in the classes dedicated to exploring LOs and called by us as ‘Carry out’, which also occurred in traditional classes, being subcategorised and allocated in the category of teacher’s action named by the authors as ‘Bureaucratic-administrative’. However, this action did not occur in classes with other didactic approaches (games and manipulative materials). Indeed, we did not categorise it because it is a common practice in formal education as it is a mandatory bureaucratic practice.

As for the action of writing, it was present in classes whose approaches were: traditional, using games and manipulative materials. In classes where the teacher used the DB and LOs for teaching and learning mathematical content, the action of writing did not occur due to the type of approach chosen by the teacher and how he/she uses the technological resources.

Threaten, Argue, Scold, Move, Organise, Request, and Provide are specific actions in classes that used manipulative materials and games.

On the other hand, some differences in the categories of teacher’s actions among the four different didactic approaches are commented in the sequence: the categories Thank, Check, Execute, Negotiate, and Congratulate are present only in classes planned with games; Reprove and Supervise categories occurred only in classes planned with manipulative materials; and, finally, categories Assist, Calibrate, Coordinate, Demonstrate, Discuss, Hand out, Expose, Encourage, Indicate, Turn on, Pay attention, Project, Carry on, Solve, Request, Suggest, and Value were observed exclusively in the classes planned with the use of the LO.

Finally, regarding the categories of students’ action, we found that Ask and Answer occurred in classes that used manipulative materials and in classes in which the LOs were explored. However, we emphasise that further research must approach the categorisation of students’ actions in traditional mathematics classes and classes the use games to highlight possible similarities and differences between the four types of planning presented here (column 1 of Table 5) and that left gaps in column 3 (first two lines).

## CONCLUSIONS

To answer the research questions, we formulated: What are the mathematics teacher’s and his students’ actions in the classroom while

exploring a LO on a DB? What connections occur between the teacher's and the students' actions while exploring an LO on a DB?, we developed categories of actions for the teacher and students, seeking to highlight the connections between their actions. In line 4 of Table 5, we have concise answers to such questions. They cannot be generalised because the actions are linked to the specificity of the situation: eight mathematics classes imparted by the teacher (subject of the research), who planned to use the technological resources described with groups of elementary and high school students.

We also justify that, as already seen in previous research, there are at least five variables that can determine the categories of action found in the data presented here (class, material, teacher, class group, and level of education), which prevent us from generalising.

Through the analysis of the information in Table 4, we noticed that the categories of teaching action did not change much, maintaining the type of lesson planning and materials used. However, the categories of students' actions change significantly according to the level of education and the type of LO chosen for exploration, but there are actions for the methodology used that they share (the use of technological resources, more precisely the exploration of a LO on a DB).

The exploration of LO in mathematics classes revealed 22 categories for the teacher's action: Assist, Calibrate, Comment, Coordinate, Demonstrate, Discuss, Hand out, Wait, Explain, Expose, Encourage, Indicate, Turn on, Ask, Pay attention, Project, Carry out, Solve, Answer, Request, Suggest, Value; and 40 categories for students' action: Accept or not, Delete, Drag, Risk, Check, Assist, Search, Celebrate, Check, Discover, Draw, Discuss, Write, Listen, Wait, Explain, Speak, Encourage, Indicate, Start, Justify, Read, Deal with, Observe, Organise, Participate, Realise, Ask, Pay Attention, Carry out, Receive, Register, Answer, Select, Feel Interested, Request assistance, Request explanation, Suggest, Take, Use.

About diversification in teacher's actions, it was possible to reveal that classes planned to use different methodological trends of mathematics education can provide a greater amount of teaching actions and, consequently, also students, compared to traditional (expository) classes, which is well evidenced in Table 5.

The results of this research also pointed out that this didactic approach, with the exploration of the LO, allowed for more active attitudes on the part of the students regarding their learning, such as moments: that

allowed them to discuss with the other students and teacher possible strategies of resolution for the LO activity, solutions for the LO activity, simulation strategies and answers to the questions of the LO activity (observed in the description of the ‘Discuss’ category in line 12 and column 2 of Table 3), which led the students to perform the action of explaining to other students how to use the simulator (LO), about possible simulations to be carried out through the simulator (LO), about the contents and activity of the LO, possible strategies for solving the questions of the activity (shown in the description of the ‘Explain’ category inserted in line 16 and column 2 of Table 3). This hypothesis remains the subject of our current and future investigations.

Therefore, we also realised that both human actors (students and teacher) and non-human actresses (media, i.e., mainly the LO and the DB) participated in the collective construction of knowledge, according to the epistemological vision of the metaphor of human-beings-with-media, whose construct, according to Souto and Borba (2016), is based on the idea that knowledge is produced by thinking collectives of human and non-human actors, in which everyone plays a central role.

We end with the information that investigations about teachers’ and students’ actions and their connections are being extended to other disciplines (chemistry, physics, and biology).

## **AUTHORSHIP CONTRIBUTION STATEMENT**

F.R.V. planned and implemented the classes and collected the data. M. M. P. and S. M. A. were responsible for supervising and guiding the research. All authors jointly discussed the results and contributed significantly to the final version of this manuscript.

## **DATA AVAILABILITY STATEMENT**

The data supporting the results of this study will be made available by the corresponding author, F. R. V., upon reasonable request.

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