The Methodological Pluralism and the Multiple Intelligences in Teaching Electrical Circuits

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ABSTRACT

This essay investigated how the plurality of teaching methodologies proposed by Laburú e Carvalho (2001) can contribute to the development of different types of intelligence in high school students. A bibliographical review was done on the theory of multiple intelligences by Howard Gardner and about the methodological pluralism with the goal of developing a democratic learning unit that would stimulate many types of intelligence and that would involve the biggest number of students possible. The data was collected through the audio taping of classes, the observation of participants and a questionnaire done at the end of the unit. To do the analysis of the data, the Discursive Textual Analysis proposed by Moraes and Galiazzi (2007) was chosen. The intelligence spectrum was defined as *a priori* categories. It was observed that some methodologies stimulate a range of intelligences that was not initially expected. Besides that, practical activities in groups demonstrated to be the best way to stimulate multiple intelligences. At last, the manifestation of eight intelligences during the research were verified, a fact that was only possible due to the diverse methodologies used.

Keywords: Multiple Intelligences. Methodological Pluralism. Physics Teaching. Electrical Circuits.

O Pluralismo Metodológico e as Inteligências Múltiplas no Ensino de Circuitos Elétricos

RESUMO

Este trabalho investigou como a pluralidade de metodologias de ensino proposta por Laburú e Carvalho (2001) pode contribuir com o desenvolvimento dos diferentes tipos de inteligência dos estudantes de ensino médio. Realizou-se uma revisão bibliográfica sobre a teoria de inteligências múltiplas de Howard Gardner e sobre o pluralismo metodológico com o intuito de desenvolver uma unidade de aprendizagem democrática que estimulasse diversos tipos de inteligência e que envolvesse o maior número possível de estudantes. Os dados foram coletados por meio da gravação em áudio das aulas, da observação participante e de um questionário aplicado ao fim da unidade.

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Para realizar a análise dos dados, optou-se pela Análise Textual Discursiva (ATD), proposta por Moraes e Galiazzi (2007), sendo o próprio espectro de inteligências definido como categorias *a priori*. Observou-se que algumas metodologias estimularam um leque de inteligências que não era esperado inicialmente. Além disso, a realização de atividades mais práticas em grupos se mostrou a melhor maneira de estimular diversas inteligências. Por fim, verificou-se a manifestação de oito inteligências durante a pesquisa, fato que só foi possível devido à diversidade de metodologias utilizadas.

Palavras-chave: Inteligências Múltiplas. Pluralismo Metodológico. Ensino de Física. Circuitos Elétricos.

INTRODUCTION

Generally speaking, the teaching of physics in Brazil remains expository, boiling down to memorization of scientific nomenclature, rules and prescriptions, to abstract concepts and to problem solving using misunderstood formulas (Delizoicov, Angotti & Pernambuco, 2009). In this regard, it is decontextualized teaching, focused on an abstract mathematical approach which results in students not being able to relate what is learned in the classroom to their daily lives.

Changes of perspectives regarding learning, influenced by the ideas of Piaget, Vygotsky, Freire and others, have reinforced the importance of valuing students' previous knowledge and experiences and making them more active in their learning process. Gardner (1993) provides an important debate on this issue by proposing that there is no general human intelligence that can define individuals as intelligent or not, but a spectrum of different intelligences that are developed differently in people. Moreover, Gardner (2001) emphasizes that education has traditionally overvalued logical-mathematical and linguistic intelligences to the detriment of developing other intelligences. This causes the false impression that many students are not as intelligent as others simply because they do not perform well when being assessed through the mainstream ways.

In an attempt to avoid conventional teaching, many methodologies have been researched into and proposed in the last decades. Often the teacher, with the best of intentions, may end up walking the beaten track and believing that, by doing so, they will guarantee good teaching and learning processes. However, as Ferreira points out (1983, p.13), sometimes:

> [...] methods are so much improved and systematized that they end up becoming the ends in themselves. Little by little obeying the principles and rules of the work and strictly following the method becomes more important than achieving the goals the method was designed for.

Teaching methodologies are instruments for achieving educational goals. However, teachers should be flexible in order to avoid that a single method ends up becoming their goal in the classroom. After all, in addition to the challenge of overcoming the idea of

students as "blank slates", one must still consider that students do not learn the same way. Regarding this Gardner (1993) argues that by limiting their methodological approaches teachers end up privileging students who can better respond to those, which favors the development of certain skills and competences to the detriment of others. Laburú and Carvalho (2001) contribute to the debate on this issue by criticizing the idea that there is an ideal and universal method to be used in the classroom. Thus, in order to reach different students, the authors believe that teachers should try to diversify their teaching strategies to the maximum and suggest the idea of methodological pluralism.

Smole (1999) argues that schools that take Gardner's theory into account should seek to develop multiple intelligences and help students within the spectrum of competences blend in harmony. Therefore, with a view to developing more democratic, critical, active teaching that respects individualities, the research question that guided this paper was: how can a learning unit on the concept of electric circuits, designed in the light of methodological pluralism, help to explore different intelligences and include more students during the teaching and learning processes? Bearing this in mind, the research aimed at identifying the manifestation of the highest number possible of intelligences during that unit, as well as verifying students' individual preferences regarding the methodologies used.

GARDNER'S MULTIPLE INTELLIGENCES

Howard Gardner's theory of multiple intelligences was a milestone in the field of cognitive psychology because it opposed the traditional view of intelligence as an absolute and measurable capacity of the human being. He stated that people do not have a single, universal intelligence that can define them as more or less intelligent, but they have different capacities that can be associated with different intelligences.

In his early books, Gardner defines intelligence as the ability to solve problems or create products that are valued in a culture (Gardner, 2001). Later he re-defines it as "a bio-psychological potential to process information, that can be activated in a given cultural setting, to solve problems or create products that are valued in a culture" (Gardner, 2001, pp.46-47). This way, he removes the purely biological conception from the idea of intelligence and highlights its psychological and cultural aspects. According to Gardner (2001), this different viewpoint defines the multiple intelligences as something that cannot be seen or measured. They are potentials that can or cannot be activated since they depend on students' culture, families, teachers, opportunities and personal choices.

Based on some criteria, Gardner (1993) proposes that different intelligences should be seen as a spectrum of competences associated with them. The different types of intelligences proposed by Gardner are classified, in a summarized way, as shown in Table 1.

Table 1

Multiple Intelligences (adapted from Gardner, Kornhaber & Wake, 1998 and Gardner, 2001).

Types of Intelligence	Definition	Examples
Linguistic	The ability to understand and use language in its various aspects.	Poets, journalists and lawyers
Logical-mathematical	The ability to use and evaluate abstract relations such as numbering objects, following chains of reasoning and solving logical and mathematical problems.	Mathematicians, engineers and scientists
Spatial	The ability to perceive space in a precise way, transform and modify initial perceptions and be able to recreate their aspects.	Artists, navigators and geographers
Bodily-kinesthetic	The ability to control and be aware of the movements of the body and / or skillfully manipulate other objects.	Actors, dancers, athletes and artisans
Intrapersonal	The ability to access and understand one's own feelings that conduces to greater self-knowledge.	Yogis and artists
Interpersonal	The ability to perceive and understand other individuals and be sensitive to interactions according to different situations.	(Religious or political) leaders and therapists
Existential	The ability to relate oneself to elements of the human condition.	Philosophers and artists
Naturalist	The ability to know about and be sensitive to the living world.	Biologists and ecologists
Musical	The ability to understand the different meanings contained in sounds, as well as to create and be able to express oneself through them.	Composers, conductors and instrumentists

By considering the multiple intelligences and observing how things are taught in schools normally, one can realize that society, in general, does not bother to stimulate students' individualities. Gardner, Kornhaber, and Wake (1998) point out that while schools have done a reasonable job transmitting information by having students memorize and repeat concepts, they have not been able to form critical citizens properly skilled to live in society. Therefore, it is important to reflect on what can be done to avoid this standardized way of teaching.

Implications of Multiple Intelligences for Education

Gardner (2001) recommends that educators teach any given concept in many ways, activating different intelligences, since such a plurality of approaches allows that more students are involved. Assuming that each topic should be treated in a variety of ways and multiple approaches should seek to enhance a range of intelligences, interests, and

abilities, the author suggests adopting different approaches to concepts, which he calls entry points, and which are presented in Table 2.

Table 2
Entry points to reach different students (adapted from Gardner, 2001).

Entry points	Definition
Narrative	Addresses students who enjoy learning through stories.
Quantitative / Numerical	Deals with students who are intrigued by numbers and existing standards.
Logical	Contemplates students interested in the deduction method.
Fundamental / Existential	Takes into consideration students who are interested in fundamental questions.
Aesthetic	Addresses students who get inspired when observing something visually interesting.
Hands on	Deals with students who can easily get involved in activities such as manipulating materials or conducting experiments.
Social	Takes into consideration students who learn better in groups, where they can consider other people's perspectives, interact and complement each other.

The diversity of entry points proposed by Gardner (2001) meets with the ideas of methodological pluralism (Laburú & Carvalho, 2001) since it recognizes that there is no single way to approach a given content. For Armstrong (2001), the theory of multiple intelligences enables teachers to reflect on their methods and understand why they work successfully with some students and not with others. Bearing this idea in mind, the author proposes a series of suggestions on how different intelligences can be explored in class, which are summarized in Table 3.

Apart from considering teaching methodologies, it is also crucial to question the evaluation methodologies commonly used in the traditional schooling. Gardner (2001) believes that assessment must be "intelligently fair", addressing all different intelligences rather than focusing only on logical-mathematical and / or linguistic intelligences. Moreover, instead of being held at the end of a school term, assessment should be done on a regularly basis as part of school curricula.

Table 3
Summary of the eight ways of teaching (adapted and expanded from Armstrong, 2001).

Types of intelligence	Teaching Activities	Teaching Materials	Students' Actions
Linguistic	Lectures, discussions, reading, writing of journals	Books, recorders, computers	Reading about something, writing and talking about it
Logical-mathematical	Problem solving, scientific experiments, mental calculations	Games, manipulative materials	Quantifying something, thinking critically about it, putting it in a logical structure

Types of intelligence	Teaching Activities	Teaching Materials	Students' Actions
Spatial	Artistic activities, mental mapping	Charts, maps, art materials	Looking at something, drawing it, mapping it mentally
Bodily-kinesthetic	Practical learning, theater, sports, tactile activities	Construction and manipulative equipment	Building something, using it, touching it, feeling it
Intrapersonal	Individualized teaching, building of students' self-esteem	Self-assessment materials, journals	Connecting something to their personal lives, choosing
Interpersonal	Cooperative learning, colleague mentoring, meetings	Games, theater accessories	Teaching something, collaborating on it, interacting according to it
Naturalist	Study of nature, ecological consciousness	Plants, animals	Connecting something to living things and natural phenomena
Musical	Rhythmic learning, songs that teach	Musical instruments	Sing something, rap it, listen to it
Existential	Reading, reflexion, debates	Texts, films	Reflecting on essential issues

The traditional evaluation process is tackled, for example, by Golin (2003) and Silva (2016). Both investigated teachers' perceptions of students' intelligences and how these perceptions were reflected upon their assessment processes. According to them teachers still consider students with more developed linguistic and logical-mathematical intelligences to be smarter, and maintain the traditional, concept-based, classification-based methods that overestimate those types of intelligence. However, Nista-Piccolo, Silva and Mello (2018) identify a tendency among some teachers to understand intelligence in a broader and more complex way, perceiving the value of abilities not related to linguistic and logical-mathematical intelligences. Nevertheless, the authors verified that such perceptions lack in sufficient theoretical reference to support a pedagogical practice focused on the development of and respect for the multiple potentialities of students. Thus, although having a less restricted view of intelligence, those teachers have not furthered their ways of educating and assessing, which may indicate the need to address the issue during both the initial and the ongoing trainings of teachers (Guzmán & Castro, 2005).

Several proposals of educational interventions that use Gardner's theory as theoretical reference can be found in literature on education. Based on a bibliographical review, Malafaia and Rodrigues (2011) propose a series of alternative strategies to explore multiple intelligences in the teaching of biology, arguing that this procedure takes into account students' different ways of learning.

Jesus et al. (2015) recognize the protagonism of multiple intelligences of high school students who, submitted to a technique of division of functions, carried out experimental activities in groups. The possibility of choosing one of six different functions allowed students to do tasks with which they identified most. This procedure was conducive to

higher motivation to participate in learning activities and to greater stimulation of abilities. Medina (2009) and Oliveira (2009) defend the use of practical and playful activities as a pleasurable way of enhancing different abilities related to students' multiple intelligences. Dantas and Aquino (2007) suggest that an efficient way to stimulate different intelligences is using educational software.

According to the authors, this type of software facilitates collaborative learning, encourages the accomplishment of extramural activities, respects each student's rhythm and contributes to the development of different intelligences by requiring different competences to undertake the tasks. These ideas are in agreement with the results obtained by Oliveira (2016) who used a virtual reality environment to make several learning objects available to engineering undergraduates. His proposal was to have each student access a virtual laboratory and complete a questionnaire devised to both identify their most developed intelligences and indicate a suitable learning object. The author reports that his proposal was welcomed by the students and that the results of the tests carried out in the virtual environment showed possible advantages to learning with customized materials. Aliciardi, Cunto and Marcucci (2016) also opted for the use of ICTs (information and communication technologies) and devised an RPG (Role-Playing Game) for computers called "Clase y Aventura" (Class and Adventure) in which each character had to do a series of activities that, in turn, stimulated the players' different intelligences. As a result, the authors suggest that games are great tools for enhancing multiple intelligences and students' motivation to learn.

Luca (2004) states that educational approaches grounded in Gardner's theory contribute to the improvement of students' conduct and learning, to the increase of both their self-esteem and interest in school issues and to the establishment of collaborative attitudes. These observations are in line with those ones of Amitha and Ahm (2017) and Çetinkil, Katırcıoğlu and Yalçın (2017) who reckon that learning based on multiple intelligences can better teacher-student relationship and improve both school environment and students' academic performances.

Several papers on multiple intelligences have been published. However, few of them have analyzed the use of Gardner's theory in the teaching of science and mathematics in high school. Rodrigues (2014) shares this same perception. The research he conducted into the teaching of optics in the light of the theory of the multiple intelligences found no similar works aiming at this segment of basic education. Therefore, the teaching of sciences, especially physics, in high schools based on multiple intelligences seems to deserve further attention in future works.

METHODOLOGICAL PLURALISM

Diversity amongst students is one of the main reasons for the use of methodological pluralism. When entering school students bring along their previous knowledge and different skills and experiences. Thus, their interests, motivations and facility for things

will be the most diverse (Laburú & Carvalho, 2001). There may be, for example, a student whose performance is poor in investigative classes, but good in lectures; or an individual who does well in classes that involve debate of ideas while in lectures is unable to focus. By adopting a plurality of methodologies during school terms one can increase the chances of stimulating learning and the development of students' all types of intelligences, as opposed to prioritizing those individuals who perform well under a single method used by the teacher.

According to Laburú and Carvalho (2001) it was Feyerabend's ideas of epistemological anarchism that directly inspired the conception of methodological pluralism. Just as the philosopher advocated a pluralistic methodology for scientific development, the authors understand that in such a complex and plural environment as the classroom, the adoption of a single teaching methodology seems inadequate to both teaching and learning processes. However, it is important to highlight that the idea of anarchism does not mean rejection of established principles. Rather, it means opposition to an immutable conception seen as the only one correct and capable of solving all problems. Pluralism, therefore, does not deny the existing methodologies, but instead, criticizes the use of a single, invariable, restricted and universally valid method. It is important to understand that all methodologies, including the less popular ones, have their advantages and drawbacks and may be useful in certain situations.

Teachers should be constantly planning and reflecting on their practices in order to choose a more appropriate methodology for a given moment. In order to fit in the pluralistic approach teachers should not allow themselves to believe in a universal pedagogical solution. Rather, they should have a creative, critical, curious professional practice, as well as never satisfy themselves and seek new solutions for different situations. They should always be willing to innovate and to examine and experiment with other approaches (Laburú, Arruda & Nardi, 2003).

METHODOLOGY

This research observed 34 students, aged 16 to 18, enrolled in three different third grade classes of a state-owned senior high school in the city of Porto Alegre.

According to Freschi and Ramos (2009) a learning unit is a flexible yet organized process that aims at fighting the sequential, closed planning in force in most school curricula and textbooks. By bearing this reference in mind, teachers can avoid behaving like replicators of sequences proposed by other authors and textbooks. Rather, they can feel free to plan their activities taking into account the context, their own convictions and their students' interests and prior knowledge. This greater autonomy strongly relates to the idea of nonconformist and creative teachers defended by the methodological pluralism (Laburú et al., 2003). Moreover, a learning unit should involve a set of activities with a view to reconstructing students' knowledge and developing their skills and attitudes. This process would, in turn, bring about more active pupils and make it possible for them

to relate what they are learning to their daily lives as well as further their knowledge in a contextualized way (Freschi & Ramos, 2009). Having this in mind, this research developed a learning unit on electric circuits hoping that, in the end, the students would understand the concepts of physics taught and relate them to the electrical components present in their day-to-day lives. In addition to that, the students were expected to be able to manipulate those components in future situations and critically discuss the process of generating electric energy. The learning unit was taught in the three target groups by one of the authors of this work.

Table 3 was initially used to identify which pedagogical actions would be most appropriate to explore the multiple intelligences. Based on this reference, the authors designed the learning unit presented in Table 4. Each lesson lasted 50 minutes. In some of them students were assigned extramural activities. These, in addition to participation in class and evaluations carried out in lessons 14 and 16, were used to replace the formal tests as assessment tools during the first three months of the term.

Table 4
Learning unit taught.

Lesson	Topic	Methodology	Entry Points	Type of Intelligence
1	Education and Society	Reading of texts and discussions	Narrative and Fundamental/Existential	Intrapersonal, Linguistic and Existential
2	Electric Charges and Electrization Processes	Historical contextualization and Experiments	Narrative, Hands-on, Social and Aesthetical	Bodily-Kinesthetic, Spatial and Existential
3	Electric Conduction	Experiments and Analysis of games	Hands-on, Social and Aesthetical	Bodily-Kinesthetic, Spatial and Intrapersonal
4	Ohm's First Law	Simulation	Logical, Social and Aesthetical	Spatial, Logical-Mathematical and Intrapersonal
5	Ohm's First Law	Exercises	Quantitative/Numerical, Logical	Logical-Mathematical and Intrapersonal
6	Electric Power and Ohm's Second Law	Experiments	Hands-on, Aesthetical, Social, Logical and Quantitative/Numerical	Logical-Mathematical, Bodily-Kinesthetic and Intrapersonal
7	Resistors Association	Experiments	Hands-on, Logical and Quantitative/Numerical	Logical-Mathematical, Bodily-Kinesthetic and Intrapersonal
8/9	Resistors Association	Simulation and Exercises	Logical and Quantitative/Numerical	Logical-Mathematical
10	Resistors Association	Card games	Social, Logical and Quantitative/Numerical	Logical-Mathematical and Intrapersonal

Lesson	Topic	Methodology	Entry Points	Type of Intelligence
11	The War of Currents	Documentaries and Discussions	Narrative, Social, Aesthetical and Fundamental/Existential	Intrapersonal, Existential
12	Electricity Bills	Investigation	Quantitative/Numerical	Logical-Mathematical
13	Household Electrics	Experiments	Hands-on and Social	Spatial, Bodily-Kinesthetic and Intrapersonal
14	Evaluation 1 – Sources of Energy	Reading of articles on the media, Debates and Writings	Social and Narrative	Linguistic, Intrapersonal and Existential
15/16	Assessment 2 – Models	Models of houses showing their electrics	Hands-on, Social and Logical	Spatial, Bodily-Kinesthetic, Intrapersonal and Logical-Mathematical

The research was qualitative and used data collected from four different sources: audio recordings of classes, activities handed in by the students, a questionnaire completed by the students and participative observations throughout the classes. The diversity of data collecting instruments allowed for identifying students' preferences for the different methodologies proposed.

The ATD (Discursive Textual Analysis), proposed by Moraes and Galiazzi (2007) and used as an analysis methodology, consists of three steps: unitization of the *corpus*, categorization of information and interpretation. According to the authors, the process of unitization requires a thorough examination of the materials by means of dividing them so as to reach the constituent units of the phenomena being studied. Categorization is the stage during which relations between base units are constructed by combining them and classifying them to form categories. As the researcher delves into the material during the two previous stages, they emerge with a new understanding of the whole. From these processes of interpretation and re-signification the researcher then produces a meta-text that presents a new combination of elements constructed in the previous steps.

The units of analysis should be defined according to something that is meaningful to the research goals and may arise from categories defined *a priori* or emerging ones. That is, when a researcher already has well defined theories and chooses to use them in the data analysis, we have *a priori* categories. On the other hand, if the aim of the research is to construct categories from the analysis, we have then emergent categories (Moraes & Galiazzi, 2007).

In this research the multiple intelligences themselves were taken as a priori categories. When choosing them one should read, reflect on and relate the referential authors so as to support the understanding of the investigated phenomena, amplify and complement the theories (Moraes & Galiazzi, 2007).

ANALYSIS OF RESULTS

It was possible to identify multiple intelligences manifested by the students during many moments of the learning unit. The students' opinions, reactions and attitudes were grouped according to the predominant intelligence in the context and were interpreted in order to produce the meta-text.

Linguistic Intelligence

As suggested by Armstrong (2001), one way of working with students who have linguistic intelligence is having them read texts, talk and write. Lesson 1 was devised as a first contact between the teacher and the students and as a way of stimulating the students' critical reflections on the role of schools in society. It was also expected that they reflected on their commitment and dedication in the classroom and on their school's teaching methodology. The students' opinions regarding the latter as well as the suggestions they made to make classes more attractive were important factors for the designing of the learning unit. In order for that to be achieved, a text was chosen to be read, and some questions were presented to be discussed so that the students could express their ideas through writing. One of the questions asked them to give their opinions about the school's teaching methodology. When commenting on that, some students demonstrated specific interests that might be related to their intelligences. The answer written by Student U, for example, illustrates the presence of linguistic intelligence:

> If there could be any change, I would like it to be about the way things are taught, the talking thing, the PowerPoint thing. I can't learn like this; I can only learn by reading texts. I also wish they would change the way we are evaluated because I think the word "test" carries a heavy weight and I am one of those that gets very nervous. I think there could be less tests and more papers and practical lessons. (Student U)

One can notice that the student criticizes the lectures that predominate in her school and states that she can only learn the concepts by reading. This strongly indicates linguistic intelligence (Armstrong, 2001). Regarding evaluation, her opinion is in line with the ideas of Gardner (2001) who states that tests are not good assessment tools as opposed to more evaluative activities in the form of papers. Although her greatest learning experience has been through reading, she is open to the possibility of being assessed through more hands-on lessons. This interest in practical activities may be related to some degree of spatial and bodily-kinesthetic intelligence, as suggested by Smole (1999).

Armstrong (2001) advocates that students with linguistic intelligence think in words and one of the ways to stimulate them is to encourage debates. With that in mind, a seminar on energy sources was held in Lesson 14. Groups of students were asked to find and bring to class newspaper articles on energy sources. All articles were read in

class, which stimulated a critical debate around generation of energy. In order for them to express the debated ideas through writing, an article posted on *Facebook* about the environmental licensing of a given hydroelectric plant was handed in. The article included some comments from users of that media that triggered a relevant debate on the subject studied. The students were asked to respond to the comments based on what they had learned in the seminar. While the articles were being given out, Student Y said:

Wow! I love answering things on Facebook! (Student Y)

This student did not usually interact much in class, so his comment reveals that the proposal of a written production linked to the social network that he is familiar with aroused his interest. In addition, the student's interest in *Facebook* reply comments may indicate that he likes to discuss and feels comfortable expressing his ideas in written form, which suggests the presence of linguistic and perhaps existential intelligences.

Logical-Mathematical Intelligence

One way to stimulate logical-mathematical intelligence in physics is by working a given content in the light of its mathematical aspect (Armstrong, 2001). In Lesson 4, in order for the students to feel freer to experiment with different situations related to electric circuits, the teacher opted for the use of a simulator devised by the University of Colorado and made available on the Physics Educational Technology / PheT page (https://phet.colorado.edu/pt_BR/), which was accessed on June 28, 2018. In order for the students to perceive the relations between the magnitudes of a circuit described by Ohm's 1st Law they had to follow a logical sequence, in which it was necessary to observe the consequences of altering certain quantities. In the dialog below it is possible to identify the reasoning used:

(Teacher) – Click on the battery and increase the voltage. What happens to the current?
(Student P) – It gets faster!
(Student N) – It shines more!
(Teacher) – Okay, what happens to the value of the current in the ammeter?
(Student N) – It rises. There is more energy.
(Teacher) – What if we increase the electric resistance of the light bulb?
(Student N) – The current gets slower. It drops.

By means of logical reasoning (logical-mathematical intelligence) the students were able to deduce that, for a given constant electric resistance, the electric current is directly

proportional to the difference of potential e; for constant voltage, it drops with the increase of electric resistance, making it easier to understand Ohm's 1st Law. Yet, the words used by the students in the dialogue indicate a more informal language and common sense. Expressions like "it gets faster" or "it shines more" show that students were still very much attached to the visual aspects provided by the simulator. Thus, in addition to the logical and quantitative / numerical entry points, the simulator also acted as an aesthetic entry point (Gardner, 2001), in which students showed interest in observing the effects due to their visually appealing characteristics and, consequently, began to transform those visual observations into logical reasoning in order to find mathematical relations. The use of a simulator, rather than a real experience, was also interesting because of the students' familiarity with the digital universe. The students saw the simulator as a "little game" and felt encouraged to curiously explore it, which is something also related to logical-mathematical intelligence (Armstrong, 2001). The aspect brought up by the activity reflects what is stated by Dantas and Aquino (2007) and Oliveira (2016). They argue that the use of ICTs in education stimulates different intelligences, has great receptivity among students and increases their engagement and motivation.

Bearing in mind that mathematical games are good stimuli to logical-mathematical intelligence (Armstrong, 2001, Antunes, 1998) and can act as social and hands-on entry points, a game of cards about electric circuits was designed to be played during Lesson 10. Although games essentially stimulate competition, Ferraz (2002, p.58) states: "the competition itself is not good or bad, it is what we make of it". Therefore, teacher mediation is important in order to avoid reinforcing excessively competitive behaviors.

Here is how the game goes: to start it, the two teams receive, each, a card that shows some characteristics of the electric circuit to be made. With this piece of information in hands the team must use the concepts learned to deduce which cards will be needed to make their target circuit. After finding it out, both teams receive, each, four starting cards and the rounds begin. In each round, a team can either acquire a card from the deck or acquire the last card discarded by the opposing team as long as they hold no more than four cards. The objective of the game is to acquire all the necessary cards in order to make one's target circuit before the opposing team does. Both the cards and the circuit can be seen in Figure 1.
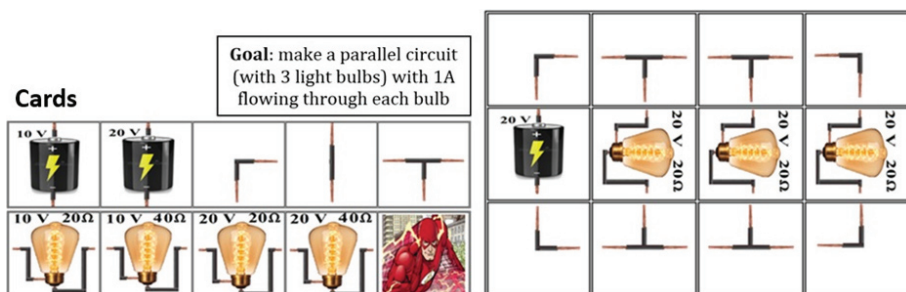

Figure 1. Cards and a sample of a circuit to be made.

To start the game the students should use their logical-mathematical intelligence and the concepts learned to figure out what cards they had to use to make their target circuit. In the dialog below one can identify the use of logical-mathematical intelligence to solve a problem:

> (Student E) – Sir, we have to make a parallel circuit with a total current of 1A. I am thinking of calculating the equivalent resistance using this formula here. Am I going the right way?
>
> (Teacher) – Ok, but you'll have to calculate the equivalent resistance for all possible card combinations. I think it would be easier for you to analyze the possibilities of currents branch-by-branch.
>
> (Student E) – Okay ... If I use a 10V battery with a 20Ω light bulb and two 40Ω bulbs, my currents will be 0.5A, 0.25A and 0.25A, which adds up to the 1A.

Despite the fact that the concepts of equivalent resistance had not been much explored in classroom up to that moment and that the teacher had devised specific examples for the game without those concepts, Student E was able to envision a sequence of calculations that could be made using the concepts learned, demonstrating the use of logical-mathematical intelligence (Armstrong, 2001). These aspects are in agreement with Medina (2009), Oliveira (2009) and Aliciardi, Cunto and Marcucci (2016) who state that ludic activities allow for the development, stimulation and manifestation of logical-mathematical intelligence.

Space Intelligence

Gardner et al. (1998) relate spatial intelligence to the ability of precisely perceiving the organization of objects in space. Having this in mind, the teacher proposed several experimental activities during the learning unit that acted as hands-on, social and even aesthetic entry points, depending on the visual appeal.

During Lesson 2, in order for the teacher to introduce the concepts of electric charges, the students were given materials they should handle to test electrification by friction and attraction and repulsion between charges. Some students had difficulty figuring out how to arrange the materials in the appropriate way for the experiment. The dialogue below shows that Student V realizes how to do it before his classmates:

> (Student W) – Sir, how do we arrange this?
>
> (Student V) – Hey, you have to put the pin underneath and the cork on top, check it out!

By observing the attempts of his classmates, Student V can mentally visualize the correct way of disposing the materials, a strong indication of the use of his spatial intelligence. Realizing that his fellow students were not able to organize the materials properly, he decides to intervene and show others how the experiment should be set up. In addition to spatial intelligence, group experiments also allow for the development of personal intelligence and reinforce the relationship between personal intelligence and cooperative learning suggested by Armstrong (2001), Luca (2004) and Jesus et al. (2015).

In addition to the classroom experiments, the students made, during Lessons 15 and 16, a model of a house in which they installed the electric circuits of the house's electrics. The ability to represent a house by means of a model already indicates the use of spatial intelligence, since this activity requires being able to perceive space and transform this perception (Gardner et al., 1998; Menezes, 2018). Nevertheless, one of the groups went further, drawing a blueprint for the house to help making the model, which indicates a well-developed spatial intelligence. Figure 2 reproduces the blueprint drawn by the group

Figure 2. Blueprint of the model house produced by a group.

In addition to spatial intelligence, the making of a model requires the use of bodily-kinesthetic intelligence, since it is related to the handling of objects. With that in mind, the models will be presented in the next section.

Bodily-Kinesthetic Intelligence

As with spatial intelligence, practical experiments are a good alternative to explore bodily-kinesthetic intelligence (Armstrong, 2001) because during the experiments, students do hands-on activities and manipulate materials and devices.

In lesson 3, for example, the students were challenged to light an LED in order to investigate which situations allowed the conduction of electric current. In the dialogue below one can identify the interest of Student X in the materials presented and his motivation in continuing to manipulate the materials to explore other possibilities:

> (Student X) – I've made it! Sir, what if I use two LEDs? Can I light two LEDs?
>
> (Teacher) – If you attach them properly, you'll be able to light them both. Try it!
>
> (Student X) – Oh, look! I was able to light two LEDs! Check it out Student T, Student U, I managed to light two LEDs!

Armstrong (2001) argues that students that have bodily-kinesthetic intelligence are interested in building devices and need to be stimulated with tactile experiences and practical learning. Student X's motivation to go beyond the teacher's request and to continue manipulating materials to build a more complex circuit clearly indicates bodily-kinesthetic intelligence. Moreover, Student X's successful achievement encouraged him to share it with his fellow classmates, indicating the role of practical activities as mobilizing agents of personal intelligence, as observed by Jesus et al. (2015).

As discussed in the previous section, the making of a model was an important activity in the development of spatial and bodily-kinesthetic intelligences. Observing the models (Figure 3) it is clear that the handling of small-scale objects and their proper organization required some fine coordination from the students, which signals that bodily-kinesthetic intelligence was used (Armstrong, 2001). As suggested by Menezes (2018), the handling of materials and the making of three-dimensional devices, besides stimulating creativity, also develops psychomotor skills, a sign of bodily-kinesthetic intelligence.
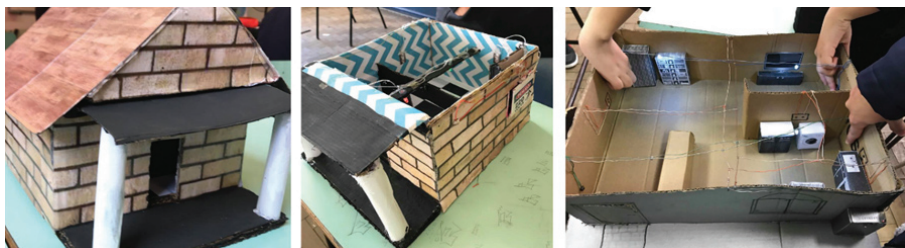

Figure 3. Models made by the students.

Intrapersonal Intelligence

Intrapersonal intelligence concerns an individual's self-knowledge (Gardner et al., 1998). One way of making use of it is through self-assessments (Armstrong, 2001). During the discussion in Lesson 1 not only were the students expected to answer the questions but also to think about how hard they had been working. This self-assessment

forced them to reflect on their actions and the reasons behind them, as can be seen in the excerpts below:

> This year I haven't been working hard enough. I confess I don't feel like coming to classes. I think it's because of my internship and having to wake up early. And it's also because I get stressed out with some teachers because of the way they teach. I would be more motivated if that could be change. (Student P)
>
> I believe I'm not doing my best at school. There are days when we feel discouraged to come to classes because sometimes we get here and we don't have two or three classes because our teachers were not able to get to school, and that's because they didn't have money for the bus tickets since our dear governor didn't pay their salaries. (Student B)

One can notice that the students put in some reflection and are aware of their little effort in school. Even so, both go further trying to understand the reasons behind their low motivation, indicating the use of intrapersonal intelligence. Student P realizes that, at this moment in her life, fatigue due to work is the main cause of her unwillingness to attend school. This report indicates that, despite having its advantages, working during school terms exhausts students and ends up affecting their school performance. It is clear that state-owned school students, who already face various educational problems, such as teachers' absences or poor school infrastructure, often have to contribute to family income. As a consequence, they have less time for their studies (Fischer, Oliveira, Teixeira, Teixeira & Amaral, 2003). As long as immense social inequality persists and basic education in state-owned schools is neglected, the quotas still seem to be the best opportunity to enter university. In fact, the problems just described explain Student B's lack of motivation. She is discouraged by the frequent absences of her teachers. However, she is aware that they are not the ones to be blamed and criticizes the educational policies adopted by the state governor holding office then.

Another interesting answer, as far as intrapersonal intelligence is concerned, was given by Student B when commenting on the importance that school has for her:

> School, for me, has been fundamental. Without it, I wouldn't be able to deal with many things in life. For example, dealing with people in my job since the job market requires people who are good at speaking in public. Thanks to the presentations we have to do in front of our classmates we learn to face our shyness. (Student B)

Because she is beginning her experience in the job market, the student realizes that there is a reason for teachers to ask students to share their findings with the group. Her comments relate to the development of intrapersonal intelligence, since activities that require students to speak in public end up making them deal with emotions such as shyness and better understand how to overcome their limitations.

Interpersonal Intelligence

Interpersonal intelligence is the ability to understand and relate to people. A good way to develop it in classroom is by providing cooperative activities that allow interaction between students (Armstrong, 2001). Previously, in the Spatial Intelligence and Bodily-Kinesthetic Intelligence sections, comments were made on the evidence of Interpersonal Intelligence emerging from the interaction of the students during some experiments. In one of them, when Student X is excited for having been able to light two LEDs, in addition to sharing that moment with his classmates, he asks his teacher:

> Sir, can I take it home? I'd like to show my dad I can light a LED! (Student X)

Armstrong (2001) argues that when students teach other people, they develop their interpersonal intelligence. The student's speech demonstrates his interest in sharing what he learned with his father, a sign of interpersonal intelligence. In addition, upon realizing that he was able to carry out the activity successfully, the student had his expectations about his own abilities increased. Thus, the practical activity seems to have had a positive effect on the student's perception of his own capability, which boosted his motivation in the classroom (Boruchovitch & Bzuneck, 2001).

The first review and exercise class (Lesson 8) aimed at working only on spatial intelligence (visualizing the circuits on paper) and on logical-mathematical intelligence (solving problems). During the exercise, however, a student had difficulty understanding it, and his classmate went to the board to try to explain:

> (Student O) – Sir, I can't understand why arrangement x is not right.
>
> (Student N) – Hey, the LED had two little legs and it would only light if we connected each terminal of the battery to each leg, because that would form a closed path. A light bulb doesn't have the legs, but it has two terminals that are like the legs of the LED. One is down here and the other one is over here.

By standing up and going to the board to explain the exercise to his classmate, Student N demonstrated to be using his interpersonal intelligence, since peer tutoring (cooperative action) is considered an important activity for the development of this type of intelligence (Armstrong, 2001; Jesus et al., 2015).

Games are also a great strategy to work with interpersonal intelligence (Antunes, 1998; Armstrong, 2001). During the card game the students interacted a lot with each other and showed that they were having much fun with the activity. Student X's team won the first round and he made the following comment after his team had lost the second:

> Okay, everyone got one. Okay, okay. (Student X)

Considering that people do not usually like to lose, the student's words seem to indicate empathy with others by signaling the use of their intrapersonal and interpersonal intelligences to deal with defeat and state that the tie was a good way to end the class since there were no losers. As opposed to the idea of competitiveness that could arise in a game, the student's speech demonstrates that he is more in line with a cooperative conception of learning with his classmates.

Existential Intelligence

Bearing in mind that existential intelligence means reflecting on fundamental issues (Gardner, 2001), this type of intelligence can be exercised by proposing debates that are conducive to students' reflection and critical thinking. In Lesson 1, some students seem to have reflected on key issues and analyzed them critically, showing that the fundamental / existential entry point provided for the use of existential intelligence.

An example of this is the excerpt below:

> I can learn the way things are taught, but I find our school's infrastructure inadequate and I feel a generalized lack of motivation among students and teachers. I believe that thinking about the students' needs when granting greater autonomy to disciplines and building timetables would be the best way to motivate everyone, including me. (Student A)

Student A demonstrates having reflected on the important role that schools play for society. For him, students should choose subjects according to their own interests. Regardless of the position assumed by the student, his critically questioning the status quo and proposing a new form of educational system is a clear sign of existential intelligence.

Naturalist Intelligence

Despite the fact that physics studies nature and its phenomena, Gardner (2001) relates naturalist intelligence specifically to the knowledge of the living world, associating it with biologists and ecologists. Considering the content studied in the learning unit, this research, at first, did not aim at stimulating this type of intelligence. However, during the debate on energy sources (lesson 14), the students could notice that some sources had environmental disadvantages due to their impact on fauna and flora. In the dialog below it is possible to identify the students' awareness of and reflection on those problems when discussing a *Facebook* posting:

> (Student G) – Tell you what, I don't know if I agree with the suspension of the environmental license. I'll have to do some research to see what's in there and see if the licensing is really a bad thing.

(Student K) – Of course it is! They were going to flood an enormous area, it would affect the fauna, the flora, the locals, the indigenous people…

(Student G) – But I'm not saying there wouldn't be impacts, I'm just wondering how we can know if it will affect the region. That's why we need more information to analyze this fact.

This awareness and concern with environmental issues indicate the development of their naturalist intelligence and is in line with Nicollier and Velasco (2009). It is interesting to notice that Student K took a more radical stance, stating that the construction of a mill in the region would cause all the problems he had read about in his research. Student G, on the other hand, took a more moderate stance, showing a more critical reflection.

Students' Evaluation of the Lessons

At the end of the learning unit, the students completed anonymously a questionnaire devised to evaluate their lessons. One of the questions asked students to rank them from 0 (I did not like it at all) to 10 (I loved it). Figure 4 shows the grades given by the students.

One can see that the lessons that involved practical experiments with electric circuits such as 3, 6 and 7 were the ones that ranked best. The classes during which students played card games, did research on electricity consumption and attended a seminar on energy sources also aroused the students' interest. On the other hand, the lessons in which the students were invited to go deep into the content mathematically through exercises, such as 5, 8 and 9, were the worst evaluated. However, it is important to note that even the classes mentioned were considered very good by some students, which reinforces the existence of diversity among them. Probably the students who liked problem solving classes were those ones who had a more developed logical-mathematical intelligence. Likewise, some classes that were very well evaluated by the majority of the students also obtained low grades from some of them. Lesson 10, for example, scored 8 or 10 in 92% of the evaluations and yet scored 2 in 8% of them.
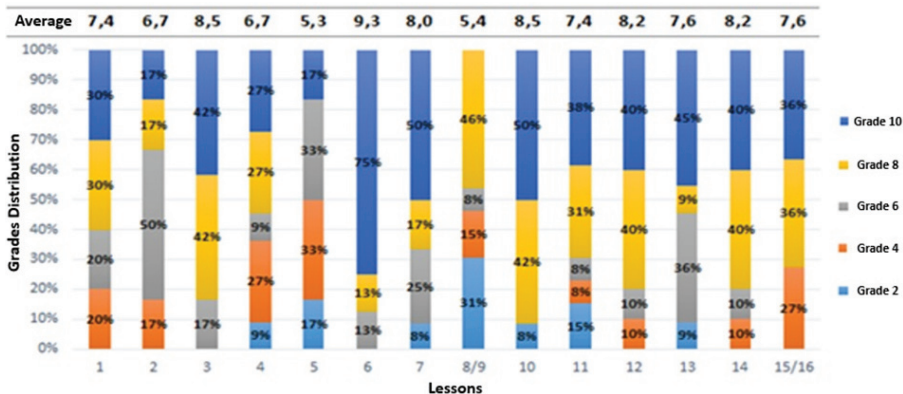
Figure 4. Grades given by students to their lessons.

It should be emphasized that no methodology was able to engage all the students. However, it was possible to reach almost all of them with a plurality of methodologies, since all those who answered the questionnaire were able to identify with at least one lesson, demonstrating, as verified by Malafaia and Rodrigues (2011), that the variety of methods is a good way to provide more democratic and inclusive education.

Generally speaking, students reported that, during the learning unit, they had to work harder than they had been used to, since they had to be active in many lessons and hand in several evaluative activities. However, as can be seen in the sections below, students said that they were more motivated during classes and found it easier to understand the contents:

> The sequence of classes demanded more effort than usual because we aren't used to thinking much. Usually the lessons are all about doing meaningless exercises. The way the teacher approached the contents made it much easier for us to understand them. I learned a lot in those classes, and I was motivated because they were different. (Student 1)

> The classes were a little more diversified and the first one was about something that isn't directly related to physics but is important. They ended up requiring more effort, because the previous teacher didn't use to teach many things. Understanding things was easier for me because of the way things were taught and I think I felt more motivated to participate because I interacted more than usual in the classroom. (Student 2)

Student 1's words make it possible to confirm that the teaching of physics prioritizes solving problems that have little to do with their daily lives. This reinforces that the traditional teaching of physics based on memorizing concepts and solving mathematical problems conduces to mechanical meaningless learning.

When saying that his teacher did not teach many things, Student 2 confirms that the group was more passive in classroom. On the other hand, this student associates his motivation with having interacted more in class, that is, with a more active role during the process. This shows that students had become accustomed to passivity, considering it comfortable, and when they were invited to participate more actively and carry out practical tasks, they found it strange at first and had some difficulty. However, at the end of the process, they understood that, although they had to work harder, their motivation and understanding of the concepts increased.

Finally, one of the students presented an argument that was different from his other classmates' ones to justify his higher motivation, as can be seen in the quote below:

> My motivation increased because I could see a teacher who loves what he does, and it made me want to learn. (Student 4)

Student 4's saying indicates the direct influence of teachers' motivation on the motivation of their students. Teachers' demotivation affects not only their planning and teaching of the lessons but also their image. The student's words precisely show the importance of teachers' image as an example for the class.

FINAL CONSIDERATIONS

Taking into account the literature reviewed in this work, one can verify that Gardner's theory can contribute enormously to more democratic, creative, critical education (Amitha & Ahm, 2017; Çetinkil, Katırcıoğlu & Yalçın, 2017). Nevertheless, this theoretical framework does not seem to reach basic education teachers in Brazil, who keep assessing their students through traditional ways that only value the linguistic and logical-mathematical intelligences (Golin, 2003; Silva, 2016; Nista-Piccolo, Silva & Mello, 2018). As observed by Rodrigues (2014), there is, in the current literature, little research on the application of multiple intelligences in the teaching of sciences and mathematics in high schools. When it comes to the teaching of electric circuits no works were found on the development of any pedagogical actions based on Gardner's theory. Thus, this work may be relevant for teachers who are interested in developing more diversified pedagogical practices that respect individualities.

This research's main goal was to verify the role that methodological pluralism can play in enhancing and strengthening students' multiple intelligences and in taking individualities into consideration. When reviewing the existing literature and planning the learning unit, it was possible to verify that there was no single method capable of developing all the intelligences present in Gardner's spectrum, which corroborates the theory of methodological pluralism (Laburú & Carvalho, 2001). As a result, it was necessary to choose a varied combination of teaching methodologies to

embrace as many intelligences as possible and respect students' preferences. During the teaching of the learning unit, it was clear that the diversification of classes proved to be positive for the research because it provided several important moments to be analyzed. As far as its validity is concerned, the diversity of methods contributed to breaking monotony and routine in the classroom and enhanced students' interest in actively participating in classes, which corroborates the ideas of Amitha and Ahm (2017). Promoting more practical activities in the classroom proved to be the best way to stimulate various intelligences, since they embraced logical-mathematical, spatial, bodily-kinesthetic and personal intelligences (intra and inter) and engage the students. Moreover, even though the activities were proposed with a view to developing certain intelligences, the more active attitude of students made it possible for other types of intelligences to emerge. As a result, some methods alone were able to stimulate a range of intelligences. Therefore, arousing the interest of almost all the students and allowing for the manifestation of eight intelligences during the research was only viable due to the diversity of methods used.

Of the nine intelligences listed, only the musical one did not show up during the research. Armstrong (2001) states that this type of intelligence can be developed, for example, by asking students to create some songs contextualizing the concepts learned. On the other hand, Gardner (2001) argues that creating songs in class does not necessarily lead to eliciting musical intelligence since students tend to resort to existing melodies rather than creating new ones. Besides, writing the lyrics for the songs, although requiring creativity, is much more linked to linguistic than to musical intelligence. As concluded by Rodrigues (2014), it is believed that the development of musical intelligence in the teaching of physics seems to be much more promising when studying wave mechanics. Still, there is room for future works to further investigation on how to properly make use of this intelligence when teaching other concepts.

Finally, it is important to emphasize, once again, the importance of nonconformist teachers present in methodological pluralism (Laburú et al., 2003). Despite the fact that the use of a plurality of methods succeeded in stimulating various intelligences, there were classes in which some students were not interested in actually taking part in the proposed activities. Just as it is not possible to state that the students did learn the concepts just because the teacher transmitted some pieces of information, one must also be cautious about imagining that the mere proposal of an activity will necessarily stimulate certain intelligences in all students. Even with positive results, one can still consider that there is room for future research works to improve teaching based on multiple intelligences and find ways to motivate the participation of all students or even provide specific activities to groups of students sharing the same type of intelligence.

AUTHORS CONTRIBUTIONS STATEMENTS

L.D. oversaw the project. G.S.O and L.D. have conceived the idea presented. G.S.O. developed the theory. G.S.O. adapted the methodology to this context, created the models,

performed the activities and collected the data. G.S.O. and L.D. analyzed the data. Both authors discussed the results and contributed to the final version of the manuscript.

DATA AVAILABILITY STATEMENT

Data supporting the results of this study will be made available by the corresponding author, G.S.O., upon reasonable request.

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